THE

THEOLOGICAL,

PHILOSOPHICAL AND MISCELLANEOUS

WORKS

OF THE

REV. WILLIAM JONES, M.A. F.R.S.

IN TWELVE VOLUMES.

TO WHICH IS PREFIXED,

A SHORT ACCOUNT

OF HIS

LIFE AND WRITINGS.

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OF THE

TENTH VOLUME.

PHYSIOLOGICAL DISQUISITIONS;

OR,

DISCOURSES

ON THE

NATURAL PHILOSOPHY

OF THE

ELEMENTS.

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Η ΠΕΙΡΑ ΣΦΑΛΕΡΗ, Η ΚΡΙΣΙΣ ΧΑΛΕΠΗ.

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On the Philosophy of Musical Sounds.

1. OF SOUND IN GENERAL.

TWO things are generally necessary to the production of sound; a sonorous body, to give the impression; and a medium, as a vehicle to bring it to the ear.

Sonorous Bodies.

The sonorous bodies of most effect are those endued with an elastic property, whose parts areso formed and accommodated to each other as to be capable of a vibratory motion when they are forcibly struck by any kind of *plectrum.* Silver, copper, and iron, which are elastic metals, are also sonorous; but lead, which is unelastic, gives no sound. Tin, which by itself has but little more sound than lead, improves the tone of copper very much

Sound how generated.

To assist our conception when we consider the medium which is the vehicle of sound, we find it necessary in philosophy to illustrate the motions of one fluid by the motions of another; of an invisible fluid by a visible one; of air by water: which method of reasoning, as applied to sound, is very ancient, the Stoics having adopted it long ago, as it is observed in the Experiments on Sounds by the Academy Del Cimento *. When a stone falls into a pool of water, the surface is thrown into waves, which spread themselves every way in concentric circles, whose common centre is the point of percussion: and when they strike against a bank, or any other obstacle, they return in the contrary direction to the place from whence they proceeded. And such is the yielding nature of fluids, that when other waves are generated near to the former, and others again near to them, all will perform their courses amongst each other without interruption: those that are coming back will pass by those that are coming forward, or even *through* them.

Reason

* Page 139.

Reason assures us, that when the fluid of air is struck by any sonorous body, it is thrown into waves similar to those of water, but much finer and sharper. From their impression we have an opportunity of seeing what they are, when a drinking-glass, nearly filled with water, is made to give a sweet ringing sound by rubbing the tip of the finger with a gentle and equable motion along the rim of it. The surface of the water appears fretted and curdled into the finest waves that can be imagined by the undulation of the air. Yet the flame of a candle, as the ingenious Mr. Hales of Dublin has observed in his Doctrina Sonorum*, is not visibly agitated when placed very near to a sonorous body of the greatest magnitude. It does not appear that in the undulations of sound there is any progressive flux of the particles of air; but that they proceed from a vibratory motion of the parts of air in their proper places: so that sound has nothing in it like the motion of the wind; though, as we shall see hereafter, the motion of the wind can act as a cause of sound.

In this particular the fluids of air and wa-

* Page 37.

ter agree, that the waves of air in sound are reflected from any obstacle as those of water are, or like the rays of light from a speculum. The sound so reflected is called an *echo*; and the reflection of a sound is so like the reflection of an object from a glass, that the expression of the Latin poets, who call an echo *imago vocis*, is equally just and elegant.

When a large circular plot of ground is inclosed with a high wall for the purpose of a fruit-garden, which has been the fashion of late years, a curious echo is produced: for when a person places himself in the centre, and claps his hands together, the sound returns very quick to the ear, and is many times repeated. At noon-day, in a garden of this sort, I could perceive it very distinctly eleven times; and if the experiment were made during the stillness of the night, I suppose it might be heard fifteen times or more: but the returns of the echo are so quick and subtile, that some who have not been apprised of this, have disputed the fact. Here the sound has the like advantage, as when the rays of light fall upon a concave mirror. If the luminous body is in the centre of that sphere of which the mirror is a segment, the rays return to a focus in the luminous point itself:

itself: and this is the case with the pulses of air in the present instance. The space through which the sound flies between every pulse of the echo, is equal to the diameter of the circle; and if it is observed to return ten times in a second over the space of 120 feet, its velocity would then be 1200 feet in a second, which is nearly the velocity of sound as commonly estimated. If the ground is level, the echo is less interrupted; on which account the surface of a calm sea is most favourable to the communication of sound. I have been informed by a gentleman of the navy, who had used the sea many years, and was captain of a man of war, that when he has entered an harbour with a high circular shore, his guns have returned a smarter sound from the land than from the ship's side; insomuch, that he had actually been mistaken, on some occasions, and supposed them to proceed from the fort he was saluting.

Air inadequate to the Phænomena of Sounds.

It seems a question more arduous than is commonly supposed, by what means sound is propagated. Natural philosophy has commonly taught, that air is the vehicle of sound: but if sound goes where no air can convey it,

through the most solid bodies, and that with the greatest ease, some other cause beside the air must concur. If this phenomenon is ascribed solely to the pulses of the air, the effect will be superior to the cause. The slightest scratching of a pin's point at one end of the largest and longest piece of timber, is heard very distinctly when the ear is applied to the other end, though it cannot be heard at half the distance when we use the air as the vehicle. This must be owing to the intervention of some cause more moveable and more powerful than air itself. If it is supposed that the particles of the wood, which are in contact with the pin's point, give motion to those that lie next them, and so on, till the vibration reaches to the other extremity; the cause is not adequate. It is therefore much easier to conceive that the effect arises from the vibrations of a medium within the pores, easily agitated, and communicating its pulses to any distance, rather than from the action of the solid parts upon one another. Then will this occult communication of sound be similar in some degree to the passage of the electric ether; which goes with difficulty through the air, but flies instantly through the pores of solid bodies.

The

The difficulty and expence have hitherto deterred me from trying the experiment; but there is reason to suspect, that sound thus propagated through solid bodies, would not be found to require the same time for its flight, as sound propagated through the open air; but would be nearly instantaneous to considerable distances. What we call air is a mixture of air and ether; and it is probable that the more moveable parts, under certain circumstances, are more easily agitated when the grosser are excluded: and this I suppose is the case when sound is propagated through solid bodies.

It is much easier to shew, to what distances, in what time, and according to what particular law, sound is propagated *through the air.*

Distance to which Sound flies.

I have heard the sound of thunder very early in a clear morning of the summer, before a single cloud was visible in a very extensive horizon; but it felt rather as if it came through the earth, by the shortest distance, than through the air. It was commonly affirmed, and I heard it spoken of when

when I was young by a very ancient person who was living at the time, that the great engagement between the Dutch and the English at sea in 1672, was heard by the people who were out at work in the fields to the very centre of England *.

When accounts are compared, it is difficult to determine whether sound is propagated farthest in its descent from the sky, or in a line parallel to the horizon. When a meteor exploded in the air at the height of 70 miles by calculation, I wonder it was never inquired into, in what time the sound passed from the sky to the earth? According to the usual computation, the explosion should have happened more than five minutes after the appearance: but, to the best of my remembrance, the accounts are silent in regard to this circumstance.

Velocity of Sound.

The velocity of sound is discovered by comparing the report of a cannon with the flash of its fire. The velocity of light is instantaneous, but sound takes some considerable time in its passage; so that the interval betwixt

* Mr. Derham says it was heard 200 miles.

betwixt these two, shews us the space that is passed over in a given time. No man ever laboured in this subject with more accuracy, and more opportunities, than the learned and philosophical Mr. Derham, author of that excellent work intitled *Physico-Theology*, in which he gives us the following abstract of all his experiments, and the result of them:
"As to the velocity of sounds, by reason the
"most celebrated authors differ about it, I
"made divers nice experiments myself, with
"good instruments, by which I found,
"1. that there is some, though a small dif-
"ference in the velocity of sounds, *with* or
"*against* the wind; which also is, 2. aug-
"mented or diminished by the strength or
"weakness of the wind. But that nothing
"else doth accelerate or retard it; not the
"differences of day or night, heat or cold,
"summer or winter, cloudy or clear, baro-
"meter high or low, &c. 3. That all sounds
"of every kind have the same motion,
"(velocity,) whether they be loud or languid,
"of bells, guns great or small, or any other
"sonorous body. 4. That they fly equal
"spaces in equal times. Fifthly and lastly,
"That the mean of their flight is at the rate
"of

"of a mile in 9 half seconds and a quarter, "or 1142 feet in one second of time."

This same subject is considered at length, and all the particulars are set down, in No. 313 of the Philosophical Transactions. If we consult the old experiments of the Academy Del Cimento, we shall see that they had established the chief laws of sound long before, and differed from Derham's measure but 6 feet in 1148. Some late experiments have been made by Mons. Condamine, in the island of Cayenne, in South America, belonging to the French. The distance, with the advantage of which he made his experiments, was above 24 miles, and the velocity came out 1175 English feet in a second of time*. The difference may be imputed to the greater rarity of the air in a climate so much nearer to the equator: and even the climate of Italy might occasion the small difference between the measures of Derham and those of the Florentine Academy.

It is scarcely credible that sound should move equal spaces in equal times, and always so nearly with the same velocity, if air were the only medium concerned in the propagation

* See Hales Doctr. Son. p. 44.

tion of sound. One of the most extraordinary facts in this whole subject is that observed by the Florentine Academy, that when a cannon is fired at some miles distance, it makes no difference, as to the velocity of the sound, whether the mouth of the piece be turned towards us or from us.

As to the force of sound, it may well be supposed to follow the law of other forces diffused every way from a centre: so that the intensity of any sound, or the force with which it strikes the ear at different distances, shall diminish in the subduplicate ratio of the distances. There are not wanting those who contend, that as such forces are extended through a sphere, and not over the area of a circle, they must diminish, not in the subduplicate, but the subtriplicate ratio of the distances. Which of these proportions is more agreeable to nature, experiment doth not seem as yet to have demonstrated.

2. Of Musical Sounds.

All motion is in time and measure: and as musical sounds proceed from motion, they must be the objects of mensuration. If they

are

are measurable by numbers, there will be between those numbers a variety of relations, so that some when compared with others shall be rational, and some irrational; and these will denote the agreements or disagreements of sounds among themselves; which are called *consonances* and *dissonances*.

The Greek philosophers measured musical sounds by numbers, and accounted for musical consonance as an effect of proportion: but Galilæo was the first who attempted to account mechanically for the pleasure we receive from musical sounds, by comparing the vibrations of a musical string with the vibrations of a pendulum.

Musical Strings analogous to Pendulums.

When two pendulums vibrate which are exactly of the same length, their vibrations are performed in equal times: if they set out together to describe equal arcs, they will consent together in their motion till they are at rest; and, if the arcs are small, all the vibrations of each, when compared with one another, will be *isochronous*. But if one of these pendulums is four times as long as the other, the vibrations of the longer will be twice

twice as slow as those of the shorter, and they shall be to each other in the ratio of 2 to 1; or, in other words, the times of their vibrations shall be as the square roots of their lengths.

A pendulum is fixed to one point; a musical string is extended between two points, and, in its vibrations, may be compared to a double pendulum vibrating in a very small arc; whence strings of different lengths, if properly accommodated in other respects, may consent in their motions after the manner of pendulums. But then it must be noted, that as a musical string is two pendulums, and not one only, it is not necessary to quadruple the length in order to make the time of a vibration twice as great; it will be sufficient only to double it.

Thus the analogy between a musical string and a pendulum gives us a more adequate conception of what could never be understood before. It gives the true reason why every musical sound preserves the same pitch from the beginning to the end, so long as it can be distinguished by the ear; and why the pitch is still unvaried, whether the sound be loud or soft. All this comes to pass, because

cause the vibrations of the same pendulum, whether they are long or short when compared among themselves, are found to be all described in equal times till the pendulum is at rest; the difference of the space which is moved over compensating for the slowness of the motion in its decay.

Two strings of equal length, tension, and thickness, by performing their vibrations together, will sound the same note, or, to speak like musicians, will be in unison. Two pipes of the same length and diameter will agree together in the same manner. In the case of the string, the air is struck by the body, and the sound is excited: in the case of the pipe, the body is struck by the air: but as action and re-action are equal, the effect is the same in either case. If the pipe were carried forward against the air as swiftly as the air is driven against the pipe, it would utter a sound, as when the air moves and the pipe is at rest.

Vibrations of Strings how to be compared.

When a string vibrates, we are to consider its motion as consisting of a *course* and *recourse;* and when we compare another string with

with it, their *concourse* or con-vibration is to be considered as the mechanical cause of their *consonance.* If their motions continually cross and contradict each other, the result is nothing but that jarring noise which we call *discord* or *dissonance.* And as it is with the strings themselves, so it is with the air, whose undulations being also subject to time and measure, will either conspire or disagree like the strings which excite them: but here the effect is too subtile for experiment, or even for imagination itself to follow it.

When two strings vibrate, one of which, A, is double in length to B, their ratio may be expressed by 2 to 1 in respect of their lengths, or 1 to 2 in respect of their vibrations; for the string A, which in length is 2, in vibration is 1; and B, which is 1 in length, in vibration is 2: the number of vibrations performed in the same time being reciprocally as their lengths. This being so, it is evident that the vibrations of these two strings must concur at every *course* and *recourse* of the longer string, so that it never makes any one pulse in which it is not joined by the shorter string. Their consonance is that of the *octave* or eighth with the *unison*.

And here I must admonish the reader, that by *unison* I always understand the note which is assumed as the *fundamental*, whatever may be the pitch of it in respect to the common scale of music.

The consonance between any two strings is more or less perfect, in proportion to the frequency of their coincidences. If the length of the longer string be 3, and the shorter 2, their vibrations, according to the rule given above, are as 2 and 3, and the interval is that which we call a *fifth*. If the shorter string, as in this example, vibrates three times while the longer vibrates twice, then of consequence it makes a first course and a recourse, and a second course, while the other makes a course and recourse; so that at every course of the longer string there is a coincidence with the shorter, and at every third course of the same the two strings return to their first position and set out afresh. If the one makes three *whole vibrations* (of course and recourse) while the other makes two, then must it also make three half vibrations while the other makes two; and thus the second *course* of the longer will fall upon the second *recourse* of the shorter, so that at every course of the unifon

Fig. 4.

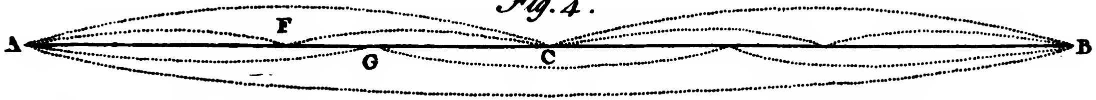


Fig. 7.

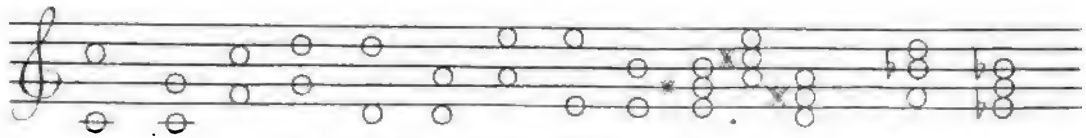


Fig. 8.

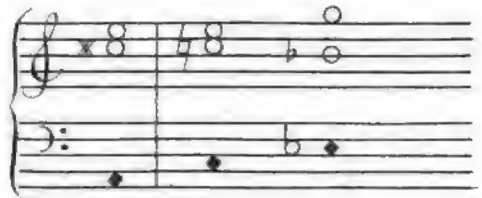
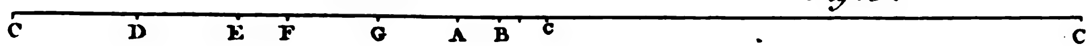


Fig. 5.



Jn.º Lodge, sculp.

unison there happens a coincidence; whence the interval of the fifth is a perfect concord.

To assist the imagination, I have made this plainer in fig. I. plate IV. wherein AB represents the unison, and CD its fifth. They are supposed to start together at E and F, and the successive asterics in each string mark the coincidences; by means of which their motions may be compared without any difficulty. In the case of the diatessaron, or fourth, where the lengths are as 3 and 4, the vibrations respectively are as 4 and 3; and the coincidences happen at the second recourse of the unison, and the third course of its diatessaron, as also at the fourth course of the unison, and fifth course of its diatessaron, in which they return to their first position.

My design being rather to shew the principle of consonance, than to pursue it through all its varieties, I shall refer the reader for farther satisfaction, in this branch of the subject, to Mr. Holder's Treatise on the Natural Grounds and Principles of Harmony, a piece which is clearly and learnedly written: and when its doctrines are understood, the seven

 ancient

ancient Greek writers upon music may be examined, of whose works there is an excellent edition printed by Elzevir, with many useful notes and commentaries by Meibomius: of these authors, the most concise and clearest is Euclid. But here the student must expect to find many things which are now obsolete, others which are very obscure, and some which will never find a sufficient interpreter. And I must also warn him not to expect more than he will find. The principle of coincidence in vibrations, as explained by Galilæo, from the doctrine of pendulums, was wholly unknown to the ancients. They contented themselves with the simplicity of ratios, as if there had been some magic in proportion, and looked no farther. They knew, that the more simple the ratio, the more perfect the consonance; and that, as they became less simple, they degenerated into dissonance. The Pythagoreans laid all their stress upon the ratios themselves: "potiores rationes potioribus consonantiis assignabant," says Dr. Wallis, in his Appendix to Ptolemy, which contains a very good and clear account of almost all that relates to the music of the ancients. Ptolemy himself

ſelf (i. 5.) speaks of one musical ratio as better than another, *κατα την απλοτητα της παραβολης*, "according to the simplicity of the "comparison." This was carried so far, that Pythagoras and his disciples would not admit a 12th to be a concord, only because its ratio 3:8 is neither *multiple* nor *superparticular*. The other great sect, the Aristoxenians, differed from the Pythagoreans in this, and trusted more to the judgment of the ear; but they were not distinguished from them by any different hypothesis with respect to the causes of consonance *.

3. *Of the Scale of Music.*

The ancients divided music into three kinds, the diatonic, the chromatic, and the enharmonic. The last of these, which divided a tone into four parts, or quarter-notes, is not in use with the moderns. The second, which proceeds partly by half-notes, is with us intermixed occasionally to produce variety, and has great effect when used with judgment and moderation; but music is en-

* The difference between these two sects, and their respective errors, are briefly and clearly treated of in Dr. Burney's History of Music, p. 453, &c.

feebled and rendered unpleasing to the ear by the intemperate application of it.

The scale in common use is the diatonic; according to which, the system of the octave consists of a fifth and a fourth, or of two fourths, consisting of two tones and a semitone, and disjoined by the interval of a whole tone. The ancients supposed these two tetrachords (or fourths) to be similar; but they are not so, as will appear hereafter.

For the systematical divisions of a musical string, mathematicians have invented different canons, which agree in some of the main principles; as they needs must do, being founded in nature; but, in some particulars, the theory admits of variety.

When a musical string of any length is extended between two points, so as to vibrate freely, we call the sound given by the vibration of the whole string the *unison*, or *fundamental tone;* to which, one half of the string will sound an octave; two-thirds will sound a fifth; three fourths will sound a fourth. Hence the interval of an octave is expressed by the ratio of 2 to 1; a fifth by the ratio of 3 to 2, or $\frac{3}{2}$; a fourth by 4 to 3, or $\frac{4}{3}$.

The most simple Division of a String.

For a first experiment, a string may be divided (by a scale placed under it) into 12 equal parts. Six of these equal parts will sound an eighth to the whole string; eight of them will sound a fifth, and nine will ſound a fourth. The difference between the fourth and the fifth is a whole tone, arising naturally from this division of the scale, and is called the tone major, as distinguished from another which is somewhat lesser. $\frac{9}{12}$, or 3 to 4, sounds a fourth to the unison; $\frac{8}{12}$, or 2 to 3, sounds a fifth to the unison; and the difference between them, which is one of these twelve equal parts, gives us the tone major. Therefore the number 12, which was preferred by the ancients, is the most convenient number of equal parts into which a string can be divided, because it shews us the interval of a complete musical tone.

Composition and Resolution of Harmonic Intervals.

Every greater interval divides itself into two lesser, of which one is always greater

 than

than the other. Thus the octave, which is in the ratio of 2 to 1, or 4 to 2, is divisible into the two lesser ratios of 4 to 3, which is the fourth, and 3 to 2, which is the fifth: and these two being multiplied together, the greater term of the one by the greater term of the other, and the lesser term of the one by the lesser term of the other, produce 12 to 6; which have the same ratio to each other as 4 to 2 or 2 to 1; the whole ratio being compounded of the intermediate ratios into which it was divided.

Then again, the fifth, which is in the ratio of 3 to 2, or 6 to 4, divides itself into the ratios of 6 to 5, which is that of the lesser third, and 5 to 4 the greater third: and these being multiplied together as before, produce the ratio of 30 to 20, which is the same as that of 3 to 2. The next step carries us to the division of the greater third, 5 to 4. If we take it as 10 to 8, it is resolvable into the two ratios of 10 to 9, which is the tone minor, and 9 to 8, which is the tone major. We double the numbers 3 to 2, and 5 to 4, taking in their stead the equivalents 6 to 4 and 10 to 8, because the ratio in the lesser terms being *superparticular*, that is, exceeding

ing only by unity, and admitting no other common measure, afford no medium.

The most ancient Greek writers seem to have been unacquainted with the difference of the two tones, major and minor; though Euclid, in his treatise on the section of the musical canon, has demonstrated that the octave, which contains five tones and two semitones, does not contain six tones: from whence the admission of the tone minor necessarily follows, and contributes greatly to the beauty and perfection of the modern scale. Ptolemy gives a major and a minor tone: but Didymus found out the minor tone long before him; only he placed the $\frac{9}{10}$ below the $\frac{8}{9}$, Ptolemy above, as we have it now. However, neither of their divisions ſeem to have been generally adopted by theorists: though it is scarcely to be doubted that the ear of practical musicians must have led them to the use of the true third 4 to 5, which does not contain two major tones, but is composed of the major and minor.

From the divisions already mentioned, we have brought a semitone into the scale; which is the interval between the major third and the fourth, or, in other words, the complement

plement of the major third to the fourth. The fourth is 3 to 4, the third major is 4 to 5, which being subtracted by multiplying crosswise, (the antecedent of the first by the consequent of the second, and the antecedent of the second by the consequent of the first,) give us the ratio of 15 to 16: that is, if the interval on a musical string, which sounds a major third to the unison, is divided into 16 parts, the half note will be one of them, and this being added to the third will constitute the fourth. This half note therefore is the natural production of the scale itself. As the tone major arises from the division of the fourth and fifth, and is the interval between them; so is the semitone the interval between the third major and the fourth.

There are other things of lesser consideration which I shall forbear to speak of. These divisions which I have explained are the proper elements of musicians in the system of the octave; which, like the alphabet in a language, afford all that variety by their combinations, with which the ear is delighted. They are found by dividing the ratios of the octave, the fifth, and the greater third, into

2 their

their component ratios; and having their grounds in nature itself, they cannot be disputed.

Theory of Coincidences resumed.

Upon the theory of coincidences, as explained above, a difficulty may have occurred to the imagination of the reader. If consonance arises strictly from coincidence of vibration, and two consonant strings should not set out precisely together, then how can they be consonant, when they are not coincident, as the theory supposes them to be? There are three ways of solving this difficulty, but I scarcely know which of them to prefer. 1. The vibrations of consonant strings are so exceeding quick *, that if there is any error in

* From experiments made with chords of vast length and small tension, calculations have been deduced, by which it has appeared, that if a small brass wire of nine inches long, stretched by a weight of 6 ½ pounds, is in unison with an organ pipe of a foot long and one inch in diameter, it makes 800 vibrations in a second; and 600 in the same time, if it is stretched till it sounds an octave higher, by four times the weight above mentioned. Mr. Sauveur's experiment to find the number of vibrations in the sound of an organ pipe of a given length in a second of time, is very natural

in the coincidence, it is too minute to be perceptible in the consonance. 2. As consonance, though mechanically from the strings, is physically from the pulses of the air, the consonance may always be just, provided the pulses of the air are of the proper magnitudes with

tural and very ingenious. Musicians have observed, that if two pipes, *nearly* in unison, sound together, there are certain instants, and at equal intervals, when their joint sound gives a stronger pulse. This he imputed to the coincidence of their vibrations at these instants. Therefore, taking two long pipes, in which the coincidences would be slower, and consequently more observable, as being rarer, and finding that their tones were in the ratio of 45 to 46, and that they concurred six times in a second, he justly inferred that a pipe of such a tone as the longer made 270 vibrations in a second of time: and that a pipe of 5 Paris feet in length had the same tone with a string that vibrates 100 times in a second. See Helsham's Lectures, Lect. XVIII. Mr. Sauveur found that a string giving the deepest musical tone which the ear could distinguish, vibrated 12 times and ½ in a second: whence a string 12 octaves higher, which is the most acute the ear can distingiush, will vibrate 51200 times in a minute; as we find by repeating the ratio of 2 to 1 (which is that of the octave) 12 times. The thoughts are bewildered when they contemplate a motion so swiftly repeated, and compare it with the single stroke of a common pendulum: yet the space passed over by the string so vibrating, is not comparable to the space which sound passes over in the same time through the air.

To

with respect to each other, and then coincidence itself will not be necessary. 3. Although we should suppose a contradiction between the two consonant strings when their motion commences, they will immediately correct this minute difference by the power of that sympathy which will hereafter be evident from many examples.

The

To explain the effect of tension in musical strings, three things are to be taken into the account; their length, their thickness, and the force by which they are extended. This part of the subject has been carried very far by more modern authors; but the principles were touched upon by Mersennus, who has three propositions corresponding to the three particulars above. 1. If strings of unequal thickness are stretched with equal forces, their thickness ought to follow the duplicate proportion of the interval required. Thus, to sound the octave below, the string must be 4 times as thick; that is, it must have twice the diameter; for the thickness is as the square of the diameter. 2. If you would ascend from one tone to a higher with the same string, it must be stretched by a force, which is the square of the interval required; for the tone in all cases will be as the square root of the extending force. 3. If strings are of equal thickness, but unequal lengths, they will be in unison if the extending forces are as the squares of the lengths.

Musical proportion is a matter of ſuch nicety, that these experiments which relate to tension never answer exactly; little insensible differences in circumstances make so great a difference in the effect.

The modern theory of music proposes the doctrine of coincident pulses as the best natural ground of consonance; and therefore I have taken it as such: but if we examine it critically, it will be found to labour under some difficulties not very easy to be solved. Upon the principle of coincidences, how hard will it be to assign a reason, why the ratio of $\frac{5}{6}$ should give us a concord, (the minor third,) and the ratio of $\frac{6}{7}$, which is next in order, an absolute discord. So also $\frac{5}{8}$, the minor sixth, is concord; $\frac{4}{7}$ discord, though the two strings coincide oftener in their motions. By the rule of coincidence, an octave is more perfect than a fifth; but by the same rule $\frac{1}{3}$, a twelfth, should be more perfect than $\frac{1}{4}$ a double octave or fifteenth; which can hardly be, while we prefer an octave to a fifth: one of the two preferences must be wrong. From the difficulty of strings not beginning exactly together, which I have just mentioned, Dr. Smith concludes, that coincident pulses are not necessary, but only accidental to a perfect consonance*. And supposing the hypothesis true, it will only do for consonances in perfect tune. Depart never so little from the strict ratio, what then will become of the coin-

* See Harmonics, p. 103.

coincidence? Yet the interval, though not absolutely perfect, shall still be consonant and agreeable to the ear: and were it not so, we should have no music that could be endured. Concords *tempered* so that their vibrations are incommensurable and not expressible in numbers, are more pleasing than discords which exactly answer to their commensurability*.

4. *Of the Monochord.*

To apply the theory of musical sounds to practice, and exemplify it to the ear, a monochord must be provided: which is an instrument contrived to exhibit the scale of music, and such as affords many curious and pleasing experiments. By its name, it is supposed to have only one string; but it is much better when accommodated with two, that one may always vibrate freely in its whole length, while the sections of the other are compared with it: for which purpose, one half of the moveable bridge must be cut down a little, that the string which passes over that part may have its liberty, while the other

* See Harmonics, p. 99, &c.

other is confined at the bridge by a spring which bears down upon it. The belly of the instrument must be very flat and true, that the bridge may be accurately adjusted: and the bridge itself must be exactly at right angles with the plane it moves upon, that its edge may correspond with the divisions below, which may be marked upon paper or a thin ruler of box. The length of the whole may be two or three feet. The form of this instrument is represented in fig. 2. plate IV.

In order to understand the sections of the monochord in dividing it, this direction must be carefully attended to; that when any section is expressed by a fraction, the denominator signifies the number of parts into which the total string is divided, and the numerator the number of those parts which must be taken for sounding any particular interval as a concord to the total string. Thus in the fraction $\frac{2}{3}$, which expresses the ratio of the fifth, the denominator 3 shews that the whole string must be divided into three parts; and the numerator shews, that 2 of those parts must be taken to sound a fifth to it. If it were required to sound another fifth above that fifth, then what was the numerator before must be made denominator, and

and taken as a new total; the two parts must be divided into 3, and 2 of them will be the fifth required. Hence the second fifth will be $\frac{4}{9}$ of the whole string $= \frac{2}{3}$ of $\frac{2}{3}$. With this direction there will be no difficulty in understanding what is meant by all the particular divisions of the monochord.

Monochord divided.

The whole length of the string between the two fixt bridges, whatever that may be, is the *unison* or *fundamental tone;* which let be C. To this C, $\frac{1}{2}$ of the string will sound an octave; the $\frac{1}{2}$ of that $\frac{1}{2}$, or $\frac{1}{4}$ of the whole, will sound a fifteenth; $\frac{1}{8}$ an octave to that; and so on. $\frac{2}{3}$ will be G, a fifth; $\frac{3}{4}$ will be F, a fourth; $\frac{8}{9}$ will be D, a tone major above the unison; $\frac{4}{5}$ will be E, the third major; $\frac{5}{6}$ will be $E^{\flat}$, the trihemitone or third minor: $\frac{3}{5}$ will be A, the greater sixth; $\frac{5}{8}$ $A^{\flat}$, the minor sixth: $\frac{8}{15}$ will be B, the greater seventh. The minor seventh, or $B^{\flat}$, if taken as a fourth to the fourth, to complete the second conjunct tetrachord of the ancients, will be $\frac{3}{4}$ of $\frac{3}{4}$, or $\frac{9}{16}$: but if taken as the minor third to the fifth, it will be the sum of the fifth and minor third when added together; that is, it will be $\frac{2}{3}$ into $\frac{5}{6} = \frac{10}{18}$ or $\frac{5}{9}$.

 Of

Of this difference in the constitution of the diatessaron we must say more in another place. Thus we have all the degrees in the octave, both in a sharp and a flat key; that is, with the greater and the lesser third. If we proceed with the scale up to another octave, each interval will be half of the former; *c d* will be $\frac{CD}{2}$, *ce* $\frac{CE}{2}$, &c. If the whole scale, or unison, is divided into 1000 equal parts, the interval between C and D, or the first tone major above C, will contain 111,11 of them; CE, the third major, (or the point at which the string must be stopped to sound the third major,) will be 200; CF, 250; CG, 333,33; CA, 400; CB, 466,66; Cc, 500: $cb = \frac{CB}{2}$, &c.

When this scale is examined, it will be found that equal intervals upon the string never mark equal intervals of sound; or, in other words, if you stop by equal differences you produce unequal intervals of sound: and it cannot be otherways; because at every stop you make a new string, shorter than the total, giving a new set of *lesser measures* for the superior notes. For want of considering this, beginners find it so difficult to understand the proportions of the monochord. Yet, after all, there is a coincidence worth observ-

ing when equal measures upon the string are compared together. Thus when the octave Cc is equally divided in F, (fig. 3. plate IV.), FB sounds a fourth to C, and CB a fifth to that fourth. In like manner, when CA is equally divided in E, EB sounds a third major to C, and AB a fourth to that third. So again, the interval GB$\frac{2}{3}$ sounds a fifth, gB$\frac{1}{3}$ an eighth to that fifth. And lastly, if AB sounds a sixth to C, AB — CA gives a twelfth to that sixth. Other concords might be pointed out upon the same principle; but these are sufficient.

Scale imperfect.

The degrees of one octave only are exhibited perfectly by this division of the monochord. If we change the key from C to some other, we break in upon the due order of the tones major and minor, and fall upon a sort of hemitones which are false intervals. Thus if D be assumed as the fundamental or key-note instead of C, the first tone as we ascend in the degrees will be a tone minor $\frac{9}{10}$, instead of what it ought to be, a tone major $\frac{8}{9}$. Hence it comes to pass, that in all keyed instruments with frets, where the tones are fixed to a certain pitch, such instruments

must be out of tune in every key but that which is adjusted as the standard, and most of all in those which are most remote from it, because the error is accumulated in every successive transition.

A Temperament necessary.

To help this imperfection, a *temperament*, as it is called, is applied in keyed instruments, to bring the tones nearer to an equality. By inspecting fig. 5, in which the seven degrees are marked in their due proportion, it may be understood, that if the major third CE is a little raised, the interval DE will be nearer to a tone major, and more like the interval CD. The like assistance is farther given by diminishing a little the interval CG, that is, by lowering the fifth: for thus the major tone FG is a little reduced, and the tone minor GA is thereby enlarged.

It is a matter of great consequence to musicians, that keyed instruments, as organs, harpsichords, and piano fortes, should be accommodated as nearly as may be to other instruments when the key is changed; and therefore that they should have nothing offensive in any key. Various are the expedients which have been used to effect this. Some

Some instruments have two different keys, to make a difference in the half note at certain points of the scale. The practical musician knows, that when B♭ is considered as a fifth to E♭, it should be something lowered; and that if the same is considered as A♯ the major third to F♯, it should be something raised; but it cannot be raised and lowered without using one key for the fifth, and another key for the third. The same is the case with E♭; which as a fifth to A♭ should be lower, and as a sharp third to B should be higher. Therefore, in some organs these keys are divided, and there are two pipes to express the semitone, according to the capacity in which it is used. The late learned Dr. Smith, Master of Trinity College in Cambridge, and author of a Treatise on Harmonics, above referred to, went still farther toward rectifying the scale in harpsichords, by accommodating occasional or supplemental jacks and strings to the different keys. I am not clear that music gains any thing upon the whole by such an improvement. The imperfection of the scale, if managed with judgment, may be no real disadvantage. The ear may find satisfaction from the different complexion of different keys, as the eye is pleased with the va-

riety of light and shade, which they call the *chiaro 'scuro* in painting. The imperfect keys may set off the more perfect, as concords are improved by the dissonances preceding. If imperfection is natural to the scale, and necessary, it may be wiser to moderate than to attempt to extirpate it. Some great masters have certainly thought that the more imperfect parts of the instrumental scale have their beauties; otherwise they would not have composed pieces for keys which are necessarily out of tune, which is the case with some very excellent compositions; and I may mention as an instance the celebrated *Stabat Mater* of Pergolesi.

If we take the pains to examine more particularly whence the imperfection of the scale arises, by summing up the intervals differently, we shall discover it first in the constitution of the diatessaron, or the degrees of the fourth. And hence it will appear, that though the imperfection in keyed instruments is in a great measure the consequence of art, yet imperfection is constitutional in the degrees of the octave, and therefore natural. For the interval of fourth includes the degrees of third major and a semitone, or of a tone major and a third minor. The third major 4 to 5

added

added to the semitone 15 to 16, give the ratio of 60 to 80, the same as 3 to 4: but the tone major 8 to 9, added to the third minor 5 to 6, give the ratio of 40 to 54; which is not the same as 3 to 4, but differs from it in the ratio of 80 to 81. So again, if we take two fourths by repeating the ratio of 3 to 4, the sum is 9 to 16: but if we compose these two fourths of their other constituent parts, the fifth and minor third, we shall have the ratio of 5 to 9. The difference is the same as before, 80 to 81. Or we may subtract 6 to 5 out of 4 to 3, and there will remain 10 to 9, a tone minor instead of a tone major; the difference is still 81 to 80.

There is another way of discovering imperfection in the scale, by comparing the fifth with the third major. The seventeenth, or double octave of the major third, is to the unison or fundamental note as 1 to 5, or as 16 to 80: but if we consider this same interval as made up of four fifths, and repeat the ratio of $\frac{2}{3}$ four times, it gives us for the seventeenth 16 to 81: whence the error of the sharp third thus obtained is 80 to 81. This quantity of $\frac{80}{81}$ or $\frac{81}{80}$ (for the order of the terms is of no consequence) which meets us in all these instances, is the famous musical

comma, or smallest *section* of the octave, and, as appears, is equal to the difference between the tone minor and the tone major: for $\frac{10}{9}$ being subtracted from $\frac{9}{8}$ give $\frac{81}{80}$. Which comma being of such great account in the scale of music, mathematicians have computed how many times this ratio is repeated within the limits of diapason, that is, how many commas make an octave. Mersennius mistook the method, and made $58\frac{1}{4}$. Holder informs us that Mercator, in a manuscript work, made 55 and a *little more*. I find by the logarithms that there are exactly 55,8 commas in the octave: and if the reader is inclined to prove it, let him take the logarithms of 80 to 81, and raise them to the $55,8^{th}$ power, and he will have the ratio of diapason, or 2 to 1, true to five places of figures, that is, to less than a ten thousandth part.

If therefore the fifths are true, the minor third, in conformity to the rest of the scale, is *naturally* too flat by a comma; so that a series of minor thirds would carry us strangely out of the way. Four minor thirds (in appearance) compose the octave: but the ratio of the minor third four times repeated exceeds the octave, and gives 1296 to 625. Hence if

if the minor thirds within the octave were all to be tuned perfect in consecution, and we were to go on so, we should gain a whole note in the compass of a few octaves. The octave is also composed (in appearance) of three major thirds: but as the others exceeded the octave, these fall short of it, and give us 125 to 64, instead of the true ratio of diapason: whence if the major thirds were made truly such in consecution, we should soon lose a whole note this way as we gained it the other.

From all this it appears, that if we temper the scale, it must be done by lessening the fifths to increase the fourths and mend the minor thirds: and as good fifths make bad thirds major, we must be content to widen the greater thirds, so that three of them may complete the octave as conveniently as may be. This is the shortest account I can give of so difficult and intricate a subject, which has exercised the deepest mathematicians, and might afford matter for endless calculations, with no great benefit to the science of music. That little comma would afford a man work enough for his life; and I apprehend he would find it untractable to the last.

Degrees

Degrees corrected by an Equality of Semitones.

An ingenious gentleman, well skilled in the philosophy of music, shewed me a monochord of his own constructing, on which he had drawn a scale, the result of a long calculation, whereby the whole system of a keyed instrument was reduced to an equal temperament, as supposing that such a temperament must, upon the whole, satisfy the ear better than any other. Being far advanced in years, he could not explain to me by memory the principles on which he had proceeded, and had mislaid the papers that contained them: but after his death, which happened very soon, first his monochord, and at length the papers relating to it, fell into my hands by the favour of a friend. I shall here subjoin a short account of them.

He denies that the ratio $\frac{3}{2}$ expresses a true fifth; for that if it did, then that ratio repeated twelve times, according to the number of half notes in an octave, would truly bisect the monochord; which it does not. For if the whole string be made 10000, and the first fifth, or interval from C to G, be taken 6666,6, and so on, (multiplying the remainder by 2 and dividing by 3, and halving or doubling

doubling the quotients as you find it necessary to ascend or descend to octaves in the progression,) then the octave to the first C will come out 4930,6 instead of 5000; which is too acute by 0069,4. To rectify this error, he proceeds by a contrary method: he supposes the string truly bisected at 5000 by a series of fifths; then he finds as many geometrical means between 5000 and 10000, or 2500 and 5000, as there are half tones between the two extremes of C unison and C octave, which are 11; the first of these means having the same ratio to the whole, or unison, as the second has to the first, the third to the second, and so for the rest. Consequently every interval or half note will be equal; and when these divisions are transferred to the monochord, an instrument tuned by that rule will be equally accommodated to all keys. When he descended to the calculation, he took the 24 half tones of two octaves, which, including the unison, make 25 terms. His first term is 2500, the double octave or fifteenth: the thirteenth term, which is the octave, is 5000; the 25th, or unison, 10000. Then, by involving the first into the thirteenth, and extracting the square root, he finds

finds the seventh term 3535,5339059327375; which being again involved into the first, by extraction quotes the fourth term. The thirteenth and twenty-fifth by the like method give the nineteenth; which might also be found by doubling the seventh term, this being an octave below the other. From the 19th and 25th he found the 22d. Having obtained these terms by extractions, and also the ratio or common excess; he multiplied the ratio 1,059463094366 into each antecedent term, and the product is the subsequent term. The ratio itself is found by the following rule: as any one term, or &c. is to the next greater; so is unity, or &c. to the ratio. The calculation was rendered exceedingly operose by his carrying the terms to seventeen places of figures, of which the twelve last are superfluous in practice. I shall suppose the monochord accurately divided into no more than a thousand equal parts; and adding one place of decimals, I shall exhibit in one column the common degrees of the octave, and in another the terms of all the semitones in two octaves, according to the above-mentioned geometrical progression.

Common

Common Scale.			Mr. Davis's Temperament.	
C	Unison	1000	C	1000
			*	943.8
D		888.9	D	890.9
			*	840.8
E		800	E	798.7
F		750	F	749.1
			*	707.1
G		666.6	G	667.4
			*	629.9
A		600	A	594.6
			*	561.2
B		533.3	B	529.7
C	Octave	500	C	500
			*	471.9
D		444.45	D	445.4
			*	420.4
E		400	E	396.8
F		375	F	374.5
			*	353.5
G		333.3	G	333.7
			*	314.9
A		300	A	297.3
			*	280.6
B		266.6	B	264.8
C	Disdiapason	250	C	250

It was scarcely necessary to continue the numbers through the second octave, because they are uniformly one half of the former: but in this I follow my author; and whoever divides a monochord, will at least proceed so far in the division.

When we tuned a harpsichord by this rule, we thought the notes were better than we had heard, and it was remarked that the chords were sensibly louder. Yet, after all, a learned ear

ear will want satisfaction in some places, and, perhaps, be obliged to retouch them a little nearer to the old proportions. The fifths in general are very near perfection, even in the extreme keys; but the major thirds E and B are very sharp, and might possibly be improved if the former were taken 796, and the latter 531: but this would introduce some other alterations; therefore I present this scale such as I find it, and think it may deserve the acceptance of practical musicians, without censuring such theorists as can please themselves better on other principles. For my own part, I am rather persuaded that a variety in the tones and semitones is not only necessary to satisfy the proportions of the scale; but that even the extreme and less tuneable keys have their beauties, and assist the effect of the more perfect ones. A musical reader may, however, be curious to try the effect of this equality, and to compare it with the common methods. And for thorough-bass in a concert, a harpsichosd might answer better when tuned by this rule than by any other.

This Invention not new.

There appeared to me something so natural and

and obvious in this scheme, that I thought the principle must have occurred to some other person before; though I am convinced the author of my manuscript was not aware of it, and that, by the steps he has taken, and the observations he has made upon them, it was to him an original invention. At length, in searching for something else among those propositions of the excellent Mersennus, which relate to the structure of musical instruments, I found a scheme of eight columns, exhibiting different divisions of the scale, for proportioning and tuning the pipes of an organ; and this equal division of the semitones, by eleven mean proportionals between the two extremes of the unison and the octave, is preferred to the first column, as the best temperament of all. The title of the proposition is —"Quæ spectant ad organorum tempera-"mentum, seu temperata intervalla, et ad "accuratam illorum proportionem explican-"dam—Hæc autem prima columna dividitur "in 13 pthongos, vel sonos, vel tubos, adeo "ut numeri intercepti inter duos extremos "1000 et 500 referant undecim medias pro-"portionales, &c." Two of these, equally distant from the extremes, he finds by calculation, and the other nine mechanically by geometrical

geometrical construction from one of the conic sections. To Mr. Davis's numbers, which are the more exact, I shall here subjoin those of Mersennus*, to shew that they are in effect the very same.

C	1000
*	944
D	891
*	842
E	794
F	750
*	708
G	668
*	630
A	595
B♭	562
B	531
C	500

When I shewed this scheme of Mr. Davis to a learned and accomplished friend†, who, while he is among the first performers of this musical age, understands the science of music deeply as a scholar, he favoured me with the following judicious remarks upon it.

First, that the scale of the octave cannot fairly be put to this test by a series of perfect fifths, because the last fifth in the series is not C, the octave to the leading unison, but B*, the

* Mersennus, P. II. p. 128.

† The Rev. Mr. Twining.

the fifth to E*, the eleventh in the progression: and there can surely be no reason why B sharp should prove to be the same note with C natural. If this reasoning would hold, we might, upon the same ground, prove that the ratio of $\frac{4}{5}$ is not the true major third; for that if it were so, that ratio repeated three times would give the octave; which it does not.

He remarked, secondly, that the same temperament which occurs first in Mersennus, is likewise found in Rameau's writings, who gives the 11 mean proportionals, as D'Alembert has also done (in Algebraic notation) in his *Elements de Musique Theorique & Pratique*, p. 52: that Couperin, a famous French organist, had proposed this method of tuning before Rameau, but afterwards rejected it. Rameau, after having strongly recommended the old method in his earlier writings, fell into this afterwards, and recommended it as the most harmonious in his last works, and has given directions how to tune in this way by the ear. But it is an insuperable objection to this method, that the major thirds are intolerable: for the fact is, that the fifth will bear a temperament better than the major third. The ear is more hurt by any temperament of

 the

the major third, than by the same temperament of the fifth. Doctor Smith proves that the simpler consonances will generally bear greater temperaments than the less simple *. His objection to all equal temperaments seems solid; that equal temperaments do not make all concords equally disagreeable to the ear. The problem therefore which he attempts to solve by his own system, and which is the great object of his book, is how to temper so that all concords, at a medium of one with another, shall be *equally* and the *most* harmonious.

I should have said little or nothing about temperaments in this Discourse, but for the papers which accidentally fell into my hands upon the subject. Without going any farther into the mysteries of temperament, I shall only observe, for the information of learners, that these three schemes are the most considerable for their simplicity: first, that which arises from the observation, that if four fifths are perfectly tuned in succession, they give the 17th or major third too wide by a comma; which error suggests the method of lowering those four fifths by a quarter of a comma each, which is about the 45th part of a note, to keep the

* See Harm. p. 120, and p. 44.

the major third to its true measure. The second scheme, is that of equal semitones, which was hit upon by Mr. Davis, but was first given by Mersennus, and after him by other writers. The third, which is the easiest in practice, and perhaps the best of all for the organ, as accommodated to the music of the church, is that of Valloti, a French organist, to which Tartini gave the preference. His method was to give to the notes of the long keys, which are most used, all their native perfection; and to throw the imperfection upon the short ones, which are most remote from the diatonic scale; that the contrast of different modulations into remote keys may have the best effect. That this method may be better understood, I have drawn out a scheme on Valloti's principle, in figure 7, plate IV.

Complemental Sounds.

Before I proceed to the consideration of musical sympathy, it may be useful to prepare the way by laying down a new doctrine (for to me it is new) of *complemental* sounds. If a string is divided into two unequal parts, so that the greater part sounds a concord to the unison, the lesser part, or complement to

the unison, will sound some other concord to the greater part; and if the point of division be very lightly stopped, both parts will sound when one is struck. Thus, if the greater part is $\frac{3}{4}$, and sounds a fourth to the unison, the lesser part, which is $\frac{1}{4}$, being disdiapason, sounds a twelfth to that fourth. If the greater part is $\frac{2}{3}$, it sounds a fifth; and the lesser being $\frac{1}{3}$, which is the half of $\frac{2}{3}$, gives an octave to that fifth. If the greater part is $\frac{3}{5}$ it sounds a sixth to unison, and the lesser part being $\frac{2}{5}$ gives a fifth to that sixth; for the fractions having the same denominators are in the ratio of their numerators. If the greater part is $\frac{4}{5}$, it sounds a major third; and the lesser part being $\frac{1}{5}$, they are in the ratio of 1 to 4, which is that of disdiapason, whence the lesser part is a fifteenth to the greater. If the greater is $\frac{5}{8}$, it is a minor sixth to the unison; and the lesser being $\frac{3}{8}$, they are in the ratio of 5 to 3, and the lesser will be a major sixth to the greater, which greater is a minor sixth to the unison. If the greater part is $\frac{5}{6}$, it gives the trihemitone or flat third; and its complement, which is $\frac{1}{6}$, is as 1 to 5, which is the ratio of the 17[th] major, or octave to the tenth. It is curious to see that the lesser sixth has the greater sixth, a

sweeter

sweeter concord, for its complement; and the lesser third has the 17th or greater third: and every concord is as it were guarded and assisted in its sweetness by some other complemental sound, which is generally better than itself. This part of the subject is nearly allied to that of secondary sounds called harmonics, to be treated of in the next section: and I think some regard might be had to it with good effect in the structure of musical instruments, where strings are stretched over a bridge: but the complemental sound should always be one of the notes of the common chord, or its octave.

5. *On Sympathetic Sounds and Harmonics.*

A sympathy is observed between musical strings when compared together; and when the same string is compared with itself, the parts sympathize with the whole. When one string is struck, another that is near it, and in concord with it, will answer it, so that its sound may be distinguished by the ear, though somewhat obscurely. When it cannot be heard, its sympathetic vibrations may be discovered by laying some light body on it, which will appear to be agitated so as even to fall away from the string: but if the same

string makes a discord with its fellow, no motion will arise in it. This effect must be supposed to depend upon the undulations of the air, which, being in a certain measure, excite corresponding vibrations in strings that accord with them, but produce no effect in those that contradict them. As the vibrations of a string produce sound in the air; so sound already excited, if of a proper measure, will produce vibrations in a string.

This sympathy between musical strings was not unknown to the ancients. Aristides Quintilianus, a writer on music, who probably flourished about the age of Plutarch, has described this experiment. His words are these: "If any person places a light piece "of chaff upon either of two strings which "are in concord, and strikes the other, even "while they are at some distance, he shall "see the string that carries the chaff very "plainly moved along with it. Wonderful "is that divine art, which can thus act upon "things inanimate! How much greater must "the effect be in those things, which, having "life and sense, are more susceptible of the "like emotions *?" This effect of music upon

* Ει γαρ τις δυο χορδων ομοφωνων ες μεν την ετεραν σμικραν ενθειη και κουφην καλαμην· θατεραν δε πορρω τεταμενην πληξειεν·

upon the human mind is most elegantly alluded to by the Royal Psalmist, that great musician of the Hebrews: *Awake, thou lute and harp! I myself will awake right early*: by which it is signified, that the mind of man is excited to devotion by the same art which excites the harp to musical sounds, and that when the one is touched the other will answer it. This sympathetic motion in the mind is an undeniable fact, though the sensation admits of no description: the sensibility of the reader will be the best interpreter. The scope of Aristides, in the foregoing passage, is to shew how natural it is that man should be moved with music, when even things inanimate are subject to its power. His reason for that natural consent which we observe between the human frame and a musical instrument is very singular. Instruments, says he, are played upon with strings and with breath; and man's frame in like manner is moved by nerves and spirits: the wind-instrument acts upon his spirits, and the stringed instrument

 acts

πληξειεν, οψεται την καλαμηφορον εναργεστατα συγκινυμενην· δεινη γαρ ως εοικεν η θεια τεχνη και δια των αψυχων δρασαι τι και ενεργησαι. Ποσω δε πλεον επι των ψυχῃ κινυμενων την της ομοιοτητος αιτιαν ενεργειν αναγκη. Arist. Quint. de Mus, lib. ii. p, 107.

acts upon his nerves. Then he asks what wonder there is in this, when even one instrument can act upon another?

There is something still more subtile than the coincidence between two different strings in concord. Every single string carries its own harmony with it. When a string is sounded, there are certain secondary and subordinate vibrations attending upon the primary: insomuch that it is questionable whether there is any such thing as a solitary sound in nature. All sounds, good and bad, seem to be a complication. Even when a fire-shovel falls upon the hearth, many sounds are produced; but the parts which produce them having no musical proportion to one another, there arises a jarring dissonance which is offensive and horrible to a musical ear. So the note of a swine is one sound made up of many others, as if it proceeded from a faggot of pipes, all of which are out of tune; and therefore the voice of a hog is very disagreeable: such as the creature is, such is its music. These jarring sounds constitute a sort of anti-music, which discomposes and depresses the mind as much as true music elevates it; and an ingenious writer* thinks

* See Collier's Essays, vol. i. Essay on Music, p. 24. P. II.

thinks this anti-music might be applied to good purpose in war, to discompose the enemy: with which view he recommends cat-calls, fire-shovels, and other instruments of that class. The sentiment is founded in nature, and the savage Indians of America put it in practice; their war-cry was invented with this view, and is said to be the most horrible sound in nature.

The Harmonic Notes.

I call those *secondary sounds* which arise from the secondary vibrations of a single string; but they are known to musicians under the name of *Harmonics*, because they are the proper and natural harmony of the note that is sounded. Their vibrations compared with the primary tone (which is expressed by unity) are in the ratio of 2, 3, 4, 5, 6, 7, 8, &c. and the lengths or sections of the string which produce these vibrations are reciprocally as the vibrations themselves. The octave, which is the first harmonic, vibrates twice, while the unison vibrates once: the twelfth, which vibrates as 3 to 1, is the second: the fifteenth, which vibrates four times, is the third: the seventeenth major, which vibrates five times, is the fourth: the nineteenth,

nineteenth, or octave to the 12th, is the fifth, and vibrates six times: the twenty-first, or flat seventh to the fifteenth, is the next, and vibrates 7 times: the next is the 22d, or triple octave, and makes 8 vibrations to 1 of the unison.

The little flat seventh, which is heard aloft, and takes its place as the 7th of the harmonics, is a musical phenomenon, not reducible to the measures of the diatonic scale. In the numbers of our monochord, the minor seventh, as a diatonic interval, is 139: but this in the harmonics, as $\frac{4}{7}$ of the total string, is 143 very nearly. The interval between this and the octave C, which is next above it, is considerably more than a tone major; whereas, by the diatonic scale, it ought to be no more than a tone minor. The tone major is 9 to 8, but this tone is 8 to 7, and the excess is something more than a comma.

Harmonics give three Sorts of Tones.

The most ancient musicians we know of admitted but one sort of tone into the system of the octave: but the series of harmonics, if we follow it far enough, give us three different measures of the tone in succession, in the ratios of 7 to 8, 8 to 9, and 9 to 10.

From

From the 21^{st} to the 22^{d}, the interval is 7 to 8; from the 22^{d} to the 23^{d}, it is 8 to 9; from the 23^{d} to the 24^{th}, (or octave to the 17^{th},) it is 9 to 10.

If we would mark the harmonics upon a monochord, it is only to be observed, that their lengths compared with the unison are these following:

Unison	1
Octave	$\frac{1}{2}$
Twelfth	$\frac{1}{3}$
Fifteenth	$\frac{1}{4}$
Seventeenth	$\frac{1}{5}$
Nineteenth	$\frac{1}{6}$
Twenty-first	$\frac{1}{7}$
Twenty-second	$\frac{1}{8}$

I go no farther in these measures than to three octaves: but the harmonics do not end there. Mersennus says, "vigesimam tertiam majorem, quæ est 1 ad 9, facile percipio circa finem soni naturalis *." By *sonus naturalis* he means the unison or fundamental sound.

In sounds of great magnitude, these occult notes are more easily perceived. When the bell of St. Paul's clock strikes, the 17th is as distinguishable as the key note, and the 12th is almost as plain to a musical ear. There

* Lib. i. Part II. p. 53.

There is reason to think that the harmonics arise in their order by ascent from the principal tone; and this agrees with what Mersennus observed concerning the 8th harmonic, or 23d, that he perceived it *toward the end* of the natural sound. I have frequently perceived it myself in the striking of a common clock, and mistaken it for the 9th, though it is two octaves higher: for we are very apt to err concerning the pitch of notes, when we have no other intermediate sounds to compare them with.

From this phenomenon of the harmonics, artists have taken a hint for the improvement of the organ by the addition of what are called its *furnitures;* which consist of ranks of smaller pipes, accommodated as a superstructure to the harmony of every single note and half-note in the instrument: and while they give a choral fulness to the organ, which is delightful to the ear, they are all subdued and melted down into the primary tones, as if they were but one and the same thing with them; though, if compared among themselves by an analysis, every full chord that is struck is interrupted with multitudes of discords in the accompaniment, which, if they were heard separately,

6 could

could not be endured; but they are all reconciled by the harmony that predominates. The stop we call the *cornet* is entirely composed of the harmonic notes, the 8th, 12th, 15th, and 17th, the last of which is essential, and constitutes the chief excellence of the combination.

When the secondary sounds proceed from a musical string, reason assures us that there must be an occult vibration of the harmonic divisions or parts of the string, subordinate to the primary vibration of the whole: that is, that while the whole has a vibration from A to B, (see fig. 4.) one half has a vibration from A to C; one third has the like vibration from A to G, one fourth from A to F, and so for the rest.

To prove that this really happens, let a string of a violin or violoncello be sounded by drawing a bow lightly across it; and, while the string sounds, let the fore-finger pass along it by sliding upwards without pressure. As the finger passes over the points of division, the harmonics will come out at those points and shew themselves, while the intermediate notes are quiescent. Thus, when the finger passes over the point F, the fifteenth will sound; when it passes

over

over G, we shall have the twelfth; C will give the octave, &c. And here it must be noted, that the tones which are heard are not produced between the finger and the bridge, as in the common way; but in the part behind, between the finger and the nut, where the string is free to make these shorter vibrations: and so the notes *fall*, when by the degrees of the finger-board they might be expected to *rise*.

There is an experiment, which belongs properly to the sympathy between two different strings in concord, and is a sequel to the experiment of Aristides Quintilianus; but I mention it in this place rather than the other, because it shews that a sympathetic string has the faculty of thus dividing itself harmonically, by points which remain at rest while the intermediate parts vibrate. If two strings be taken, of the same thickness and tension, the shorter of which is one foot in length, and the longer four feet, they will be in the ratio of disdiapason. If the shorter string is sounded, it will be answered by the four equal parts of the longer; and if fome light particles of chaff are laid upon it, one at the extremity and one at the middle of every foot, the particles at the intermediate distances

distances will be thrown off by the tremulous motions of the string in those places, while those upon the quiescent points will be undisturbed *.

Trumpet Marine.

They who are acquainted with the performance of the *trumpet-marine*, so called because it expresses the same intervals with a trumpet, know that its notes are those only which we call the harmonics. This instrument, which is also called a monochord, has only one string stretched upon a pole, in the manner of a bow-string. When it is stopped by the side of the finger without pressure

* For this elegant experiment, which we have repeated several times and find it answer, Mr. Hales refers to the Philosophia Britannica of Mr. Benj. Martin, vol. ii. p. 264. I will add what follows, in the words of Mr. Hales, though the fact is commonly known, and given as a remarkable instance of the sympathy of sonorous bodies: "Huic quoque "constat ratio scyphum vitreum ope vocis perfringendi. "Qui experimentum instituere cupit, ictu prius in scyphum "impacto exploret sonum huic proprium: deinde, ore supra "scyphum applicato, vocem unisonam edat, eandemque paulatim intendat: scyphus vero primum contremit, tum "stridet, atque ultimo, ni vitrum justo crassius sit, diffringitur." Son. Doctr. p. 51. See also Mr. Rowning's Dissertation on Sound, of whose words this Latin seems to be a translation.

pressure at the proper points, and struck at the same time with a bow, the string gives the whole harmony of the unison, and nothing else. The trumpet and French horn leap spontaneously to the same notes: and, what is more, I have been assured by my own son, who is acquainted with music, that he has heard several of the harmonics very distinctly from the wind blowing into the barrel of his gun as he walked along the field.

Tartini's Experiment.

Another property of sounds, more subtile and wonderful than any of the foregoing, was first observed by that eminent master Tartini, a man of deep speculation in the science of music, and a great artist, though somewhat eccentric in his opinions *. He found, that if two notes are sounded in concord,

* I am informed by my musical friend, that a Frenchman, M. Romieu, member of the Academy of Sciences at Montpelier, was beforehand with Tartini in this discovery. He presented to the Society, in the year 1753, before Tartini's book was published, a memoir relating all the detail of the experiment. This is mentioned by M. D'Alembert in the Preface to his Elemens de Musique. However, he supposes both these persons to have been original discoverers, though Romieu was first.

cord, either by one or more instruments, or by voices, a third note is produced to complete the harmony. Any musical reader may try this upon the harpsichord. Let him strike at once, with the harpsichord open, the two first white notes of fig. 8, and he will hear the third little black note produced below, which is the fundamental note of the key, the unison which would produce those two notes among the number of its harmonics. If he strikes C ♮ with E, as in the next example, then the key note of C will answer in the double octave below. If he strikes B♭, with G the fixth above it, E♭ will be produced below, being the key-note of the harmony. More instances are given by the ingenious commentator on Tartini, the late Benjamin Stillingfleet, efq.* and many more by Tartini himself: but they all depend on one principle; and in order to find what the corresponding third note will be in every possible

* See a book called The Principles and Power of Harmony, printed for Baker in York-street, 1771. The learned author, whose fkill was by no means confined to this science, did me the honour of sending me his book by the hand of a friend. It contains many things worthy of a musical reader's attention, whatever becomes of the main hypothesis.

possible case, we have only to consider what one particular fundamental would produce the two given notes as its harmonics, (for it can be only one,) and that will be the note we shall hear below. The observation must occur to the reader of itſelf, that this case is the converse of those we have considered before. There, we saw some one lower note producing its harmonic accompaniments; here, we see the harmonics in their turn producing that lower note. For want of knowing this principle, Tartini and his commentator have ſometimes referred us to the wrong note. When the upper notes are struck, it requires some time before their vibrations produce the corresponding sound in the note below; but if it is waited for, it will be heard distinctly enough.

When these upper notes lie in an instrument which is furnished with lower strings capable of yielding the expected note, the case is less wonderful: but the third sound is still heard, when there is nothing but the undulation of the air to produce it; as if harmony were congenial to the element. The learned commentator on Tartini gives us from his author the following account of the fact: "Two "sounds being given on any musical instru-

"ment,

" ment, which will admit of their being held " out for any time, and of being strengthened " at pleasure, as on the trumpet, the German " horn, the violin, hautboy, &c. a third " sound will be heard. The same thing will " happen if the same intervals be sounded by " two players on the violin, distant from one " another about 29 or 30 feet, always using " a strong bow, and holding out the notes. " The auditor will hear the third sound much " better if placed in the middle between " them, than if nearer to one than the other " Two hautboys will produce the same effect " placed at a much greater distance, even " when the hearer is not in the middle, but " much more if he is*." Dr. Burney heard the same effect produced in Germany between two human voices, Guadagni and Rauzzini †.

We are now to inquire how this effect is brought to pass. My learned friend, whose name I have already mentioned, proposed to me the following solution; and it is undoubtedly the true one. Suppose the two notes that are sounded are the fifteenth and the seventeenth: their vibrations coincide at

F 2 every

* Principles and Power of Harmony, p. 5.

† See his German Tour, vol. i. p. 199.

every fifth pulse of the upper note, and at every fourth pulse of the lower note: and when they conspire, the vibrations of each become more intense, so as to be distinguished by the ear. But their coincidence happens exactly at the same intervals with the vibrations of the fundamental note or unison, and thence the unison is heard as the third sound. The lower tone would hit the unison at every fourth vibration; the higher would hit the unison at every fifth vibration. Now let the unison be removed, and they meet each other where each would meet the unison; and thence the sensation of the unison is excited. Whether there is a third sphere of undulations produced in the air by the concurrence of the other two, is a question of some difficulty; but, without supposing it, the effect must be referred rather to the imagination than the senses. The same solution of this curious phenomenon was given by a learned foreigner, Mons. Serre, of Geneva: but the gentleman who communicated it to me had hit upon it before he saw it confirmed by this author.*

The

* Il me paroit au reste assez aisé d'expliquer l'origine de cette espéce de burdon, de ce son grave et fondamental, qui est ici produit par la concurrence de deux sons aigus. Ce n'est,

The 19th section of Aristotle's Problems is upon the subject of music only; and though the whole of it is very obscure, at this distance of time, to us who have other modes of music, and are not clear in the meaning of his terms, there are some passages in which he observes that grave sounds are attended by more acute ones; and here he has probably alluded to what we now call *harmonics*. But Mersennus thinks he himself was the first * who ever observed them particularly, and treated of them philosophically. He does not account for them from the secondary vibrations in the harmonic portions of the string, but from an acceleration in the pulses of air, occasioned by the reiterated vibrations: as if the first stroke excited in the air a vibration of its own measure; the second made that vibration twice as quick, and produced the octave; the

 third,

n'est, a mon cens, qu'une apparences acoustique occasionee par la suite de vibrations coincidentes de ces deux sons—ces vibrations coincidentes, qui se suivent avec plus ou moins de rapidité sont exactement isochrones aux vibrations que feroit réellment la son fondamental.—Essais sur les Principes de l'Armonie, par M. Serre, p. 115.

* Fortè primus animadverti, cur idem nervus plures sonos, tam acumine quam vi discrepantes, eodem tactu producat.—Harmon. P. II. p. 47. prop. 29. vide etiam prop. 33. p. 53.

third, the twelfth, and so on, still keeping up the original measure as the fountain of all the rest. But this solution of Mersennus is overthrown by the experiment which discovers the quiescent points of the string.

6. On the Eolian Harp.

It was observed above, that as action and re-action are equal, the effect is the same, whether the sonorous body strikes the air, or the air strikes the sonorous body. In the case of a musical pipe this is plain enough; but it was not so well known, nor could it be so familiarly proved, till of late years, that the air can begin of itself to produce the effect, and fetch music out of a string, as a string fetches music out of the air. We have now a curious illustration of this fact from the instrument called an Eolian harp. How far the ancients were masters of this experiment is uncertain: but it has long been known, that the wind would bring musical sounds from the strings of an instrument. In the Jewish Talmud, where we should scarcely expect to find any thing valuable in philosophy, the wind is reported to have brought music out of the harp of David; which, as it is

is there said, "being every midnight con-
"stantly blown upon by the north wind,
"warbled of itself*.

The same effect has been alluded to by some of the poets, particularly by our own English poet, Spenser, where, speaking of the visionary harp of Orpheus, he has the following lines:

"I *saw* an harp strung all with silver twine:
"At length out of the river it was rear'd,
"And borne about the clouds to be divined;
"Whilst all the way most heavenly noise was heard
"Of the strings stirred with the warbling wind."

Spenser's Ruins of Time, III. 2.

The author of the Principles and Power of Harmony ascribes the invention of what we now call the Eolian harp to Father Kircher; and it may be found in his Phonurgia, p. 148. In Mersennus, who endeavoured to pick up every thing the world could afford him, I see nothing of it. To the best of my knowledge, it was not taken from either of these authors, when it was revived of late years in England. When Mr. Pope was translating Homer, he had frequent occasion to consult the Greek commentary of Eustathius; where he met with a passage, in which it was suggested,

 that

* Talmud, in Berac, fol. 6.

that the blowing of the wind against musical strings would produce harmonious sounds. This was communicated to Mr, Oswald, a master of the violoncello from North Britain, and an ingenious composer in the Scotch style, who himself gave me the following account many years ago, when I was under him as a practitioner in music. When he had received the hint of Mr. Pope's discovery in Eustathius, he determined to try whether he could reduce it to practice. Accordingly he took an old lute, and having put strings upon it, he exposed it to the wind in every manner he could think of; but all without effect. When he was about to give the matter up as a mystery or a fable, he received some encouragement to a farther trial from an accident which happened to an harper on the Thames; who, having his instrument with him in a house-boat, perceived that a favourable stroke of the wind brought some momentary sounds from the strings, as if they had been suddenly touched after that manner, which, from the genius of this instrument, is called *arpeggio*. The man was alarmed with the accident, and made many trials to procure a repetition of the same sounds from a like turn of the wind, but could never succeed : the

the music was vanished like an apparition. Upon this ground, however, Mr. Oswald persevered; and it came at last into his mind, that perhaps the strings ought to be exposed to a more confined current of air. With this view he drew up the sash of his chamber-window, so as to let in a shallow stream of air, and exposed his lute to it. In the middle of the night the wind rose, and the instrument sounded; which being heard by the artist, he sprang out of bed to examine all the circumstances of its situation, and noted down every thing with the most scrupulous precision; after which, as the principle was now ascertained, he never failed of the effect *.

The construction of an Eolian harp is very simple. Nothing more is necessary than a long and narrow box of deal, with a thin belly, and eight or ten strings of catgut lightly stretched over two bridges placed near the extremities, and all tuned in unison. When

* That the effect of the Eolian harp must often have been heard by accident, seems undeniable from what I was lately informed of by Mr. Stanley, composer to his Majesty; that two wires stretched across an area before a house at London, had been heard to make very fine music, equal to the best Eolian harp.

When it plays, the unison itself is plainly heard as the lowest tone, and the combinations of concords, though consisting chiefly of the *harmonic* notes, are by no means confined to them, but change, as the wind is more or less intense, with a variety and sweetness which is past description. I know not how to account for the compass of its notes on the principles of the harmonics, but by admitting a new species of sounds, which I call *harmonics of the harmonics*, or *secondary harmonics*. The sharp seventh is very commonly heard, which, if deduced as an harmonic, must be of the second species, as the 17^{th} of the 12^{th}; as also the 9^{th}, which is as frequently heard, may be taken for the 12^{th} of the 12^{th}: and thus, perhaps, we may account for all its varieties.

If we consider the quality of its harmony, it very much resembles that of a chorus of voices at a distance, with all the expressions of the *forte*, the *piano*, and the *swell*. In a word, its harmony is more like to what we might imagine the aerial sounds of magic and enchantment to be, than to artificial music. We may call it, without a metaphor, the music of inspiration.

With respect to the peculiar nature and causes

causes of this phenomenon, I dare not promise entire satisfaction from my own speculations, being well aware of the difficulty. The principles I shall offer for solving this wonderful effect, are founded on the analogy between light and air.

1. And first I lay it down, that music is in air as colours are in light. When any body inflects the rays of light or refracts them, it does not give the colours that are seen, but it makes the light give them: so a sonorous body does not give musical sounds, but makes the air give them.

2. That as colours are produced by inflections and refractions of the rays of light; so musical sounds are produced by similar refractions of the air. There is no reason to suppose that air is homogeneous in its parts, any more than light: and if air consists of heterogeneous parts, they will be differently refrangible according to their magnitudes, and excite different sounds, as they are accommodated to different vibrations, and capable of different velocities; as the parts of light which are differently refrangible give different colours. The parts of air most refrangible will excite the most acute sounds;

and

and the smallest parts will be most refrangible *.

3. That as light shews no particular colour but by means of some other intervening body to separate and modify its rays; so the air yields no particular musical tone without the assistance of some sonorous body to separate its parts, and put them into a vibratory motion.

4. That as light is refracted into colours, not only on dioptric principles, by passing through a prism of glass, or some other refracting medium, but also by passing near the edge of some solid body which inflects it out of its course; so is the air subject to be refracted by a similar inflexion. It would require much time and observation, more than I have had leisure to bestow, to expand this principle into a theory, and confirm it by proper

* This notion concerning the different degrees of subtilty in the parts of air occurred to Mr. Derham; who argued, that as sound moves near 1200 feet in a second, and the most violent wind not more than 60 miles in an hour, which is at the rate of 88 feet in a second, the particles of air which communicate sound must be more subtile than those which constitute the winds. See Hales, Doctr. Son. p. 47. If wind acts by the grosser parts of air, and sound by the finer, this may be a reason why they do not interfere nor disturb one another's motions.

proper experiments: but the fact seems clear, that sound is produced, and that air becomes *vocal*, on this principle of a *refraction*. As the Eolian harp plays by an inflexion of a current of air over the edge of an aperture, so the column of air in an organ-pipe becomes vocal by means of a shallow current which strikes against the edge of the aperture, and is thence inflected into the cavity of the pipe. In the German flute also, the breath gives the tone by passing over the edge of the aperture; and, according to its intensity, it produces higher or lower tones as the wind does in the Eolian harp. It would be endless to pursue this effect under all the various shapes in which it appears to us. It is sufficient for our purpose, that we have many instances, in which air becomes vocal and musical, by suffering a kind of refraction against the edge of some solid bodies; for this is the case with the Eolian harp: the wind passes to the strings of the instrument by the edge of an aperture; whence it is inflected, partly at a greater, partly at a lesser angle: and that portion of the current of air which makes a different angle with the plane in which the strings lie, excites a different tone. I have expressed my meaning in plate IV. fig. 6. where

where A is the aperture, P a pencil of air, *a*, *b*, *c*, *d*, a section of the strings, receiving the impulse of the air at different angles.

This hypothesis for the solution of Eolian sound by a refraction of the air, is recommended by an experiment, which demonstrates that such a relation between air and light as we have here supposed, is not imaginary. For as light, when refracted, affords us seven colours, and no more; so the air yields seven degrees of sound within the system of the octave; of which all successive sounds, however multiplied, are but repetitions. I met with this comparison in an ancient English author: but the sagacity of Newton hit upon it in his optical experiments, and he has carried it much farther, by shewing us that the analogy extends even to the respective intervals of each. The prismatic spectrum, under his accurate examination of it, was found to exhibit the same degrees with the series of tones and semitones in an octave: but they do not answer to the degrees of the octave either in a flat or sharp key, as these keys are commonly now used; because the third is minor, and the sixth major. However, these degrees of the optical octave may be justified, and the old masters have

have composed according to them; of which we have an instance in the old Creed of Tallis; and there are many others. The diatonic scale affords us two octaves with the minor third, which differ in their degrees: the one from A to A, with the minor third and minor sixth: the other from D to D, with the minor third and major sixth. This latter has the advantage in two respects: 1. It is more simple and natural, because the two tetrachords which make up the octave are similar; that is, they both have the hemitone in the same place, as it happens in the two tetrachords of the major key. 2. It leads to a greater variety of modulation; and though the harmonies by some are accounted harsh, yet in my opinion they are more stately and pleasing than in the flat key with its two dissimilar tetrachords, as now managed by modern masters; who have entirely dropped the other form, though it has excellencies peculiar to itself, and therefore deserves to be retained.

The analogy between sounds and colours is very strict, and may be carried very far. In the order of the seven colours, three of them are simple and primary, the *red*, the *yellow*, and the *blue*: so in the seven degrees

of the octave, there are three principal tones which constitute its harmony, the *unison*, the *third*, and the *fifth*; and these have the same places in the series as the three simple colours have in the prismatic spectrum: *red* is in the place of the *unison*, *yellow* in the place of the *third*, and *blue* in the place of the *fifth*. All harmony, though the parts are never so many, is made up of these three sounds, as all hues are composed of those three colours.

Upon the whole, the Eolian harp may be considered as an air-prism, for the physical separation of musical sounds. The form of it may be improved, so as to give a farther illustration to the principles I have adopted. Instead of fixing the strings to the outside, I dispose them upon a sounding board or belly within side a wooden case, and admit the wind to them through a horizontal aperture, so that the affinity of the instrument to an organ-pipe appears at first sight: and thus it becomes portable, and useful any where in the open air, instead of being confined to the house; which is a great advantage*: and

† I made an Eolian harp of this construction, and sent a model of it, upon a small scale, to Messrs. Longman and Broderip in Cheapside, who have worked upon it under my direction

and it is probable this new form may lead hereafter to some new experiments. See Plate IV. fig. 9.

No person of a musical ear can listen to the Eolian harp, without discovering that the sound varies with the *intensity* of the wind. The unison with a sudden gust will change immediately into the octave on the same string; which happens in other instruments: the Common and German flutes give the octaves with a more intense blast of the breath. What seemed to me most inexplicable of all, was this, that if the Eolian harp is exposed to the air with a single string, that string, without any change in its situation, will be heard to sound all the harmonic notes, which are seven or eight, beside the unison, and several of them will be heard at the same time. When many strings, which the wind meets at different angles, sound together, we have not only the harmonics of the unison variously produced, but harmonics of the harmonics, as above mentioned.

rection, and will be prepared to dispose of them at a reasonable price to such gentlemen as take a pleasure in this agreeable class of experiments.

7. On Style and Method in Music.

My design in this discourse was only to touch upon the philosophical part of music; but if I step a little beyond that line, now the subject is before us, I hope no lover of the science will be offended with me. One branch of the science of music, and that of no small importance toward the effect of it, seems to be but loosely understood, and but little attended to: indeed there are some composers who seem to have no idea of it: I mean the great art of *method* or *style* in music, without which the most laboured composition is a rhapsody of nonsense. I could never find any thing satisfactory upon this subject in any writer; nor do I know whether there is any word extant to express the thing I am speaking of, unless it be the word ῥυθμος, *rythmus*, as it was applied by the ancients. To this term Suidas gives the following definition, ταξις εμμελης * ακολυθυ αρμονιας, *an elegant order of consequent harmony.* This comes nearly up to my meaning: for *consequent harmony* is just and pleasing when the melodies which come after have a due

* Falsely printed εμπελος.

due proportion and agreement with those which went before; and it never can be pleasing, unless this relation is properly kept up in the course of a composition. Though the ways of carrying on a subject may be infinitely various, according to the fancy and choice of the composer, yet they should all be under the restriction of some rules, that there may be a just measure and proportion through the air or melody of the whole piece. The common sense and experience of great masters has enabled them to succeed in most cases, without transgressing the due measures of their subject: and perhaps there have been certain precepts amongst them for this purpose, though they are not found in books.

Sometimes it has occurred to me, that as Aristotle drew the rules of poetry from Homer's works; a critical commentary, in the way of an analysis, with a particular view to the matter I am speaking of, might be written on the music, or some of the music, of Corelli and Geminiani, particularly their concertos, which would afford some of the best rules for methodical composition; at least, such as are no where extant; if some master, of judgment and learning sufficient, would be at the pains to extract them: though

at the same time I think neither of these authors, particularly the latter, are absolutely free from error in the conduct of their measures. The common rules relating to concords, discords, resolution, and the varieties of thorough-bass, are every-where to be met with: but such a piece as I wish to see, would be an acquisition in music, like Hogarth's Analysis of Beauty in painting and design: it would be what Horace's Epistle de Arte Poeticâ is, when compared with the Prosodia of Lilly's Grammar; or Demetrius, Longinus, and Cicero de Oratore, when compared with the common syntaxis.

If the artist would please us with the management of his subject, he must consider the reason why we are pleased with the harmony of concordant sounds. Is it not because they are all measured out to us in certain proportions? Have they not their proper ratios and coincidences, without which they would be absurd in themselves, and displeasing to the ear? Every musical subject must, in like manner, and for the same reason, be under the restrictions of *isochronism* and *commensurability*: it will otherwise be nonsense; and though the ignorant may think there is something in it, a person of better taste must

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be disappointed and disgusted. When an orator discourses upon any matter, he must divide it and dispose it into an orderly method; without which his hearers can neither be moved nor instructed, because they cannot understand where he is, nor what he is doing. Every sentence in his speech must have some reference to the main subject, so that it may appear manifestly to be related to that subject rather than to any other. If many of its sentences might as well stand any-where else, then we must pronounce it to be an incoherent rhapsody, without judgment or meaning: and the more the speaker is agitated in delivering such matter, the more he exposes himself. The composer of music should be as strict in dividing, and as careful in adhering to the subject he has chosen. If twenty bars of his piece might as well stand any-where else as in the strain where he has placed them, he either wants to be better learned in his art, or he has forgotten what he was about; and thus his music becomes impertinent, and the finest execution in the world will be thrown away upon it.

To produce variety, and yet avoid an injudicious departure from the subject, learned masters of music have invented all the arts

of inversion, reversion, augmentation, diminution, division, modulation, &c. that, with the changes of the melody, a sameness or commensurability may still be preserved in the composition. All the beauty with which we are justly charmed in the works of art, consists in *variety with uniformity*. The principle may be extended almost to every thing: to music it certainly may; in which, if it is good, there must be an harmony in the *measures* as well as in the *sounds*, so that the piece may be consistent and rational. Hence the *fugue* and the *canon*, in which the melodies are more strictly commensurate, are the most perfect kinds of composition: and yet the varieties are so great, that they will bear to be repeated longer before the ear is master of them, than any other kinds of music whatsoever. What is the reason why all common ears are pleased with minuets, gavotts, hornpipes, country dances. &c. but because the music is all confined to a certain measure in the number of the bars of which they consist? Why are good variations so generally pleasing, but because there is a plain reference all the way to an original air? so that the memory compares what follows with what went before, and the judgment is

delighted with the truth of the correspondence. Music which has not something of this correspondence, is a species of lie, and the judgment cannot approve of it. I do not say that all music should be divided by strict mathematical rules: it cannot be; it ought not to be; because, in vocal music, the notes must be subservient to the words. When the words have metre, the music will have it; but when the words are prosaic, the music will be so too. Complex music must differ from strains of a stated measure, as prose differs from verse; and there a greater latitude must be allowed. Yet prose may be very absurd and inharmonious, unless the cadences are just, and it is properly connected and divided *. When a subject in music is laid down, it ought to be preserved in some form or other throughout the whole

 piece:

* My meaning here is very nearly expressed by Cicero in his directions concerning the harmony of prosaic oratory. "Id in dicendo numerosum putatur, non quod totum con-" stat e numeris, sed quod ad numeros proxime accedit.-- "Multum interest utrum numerosa sit, id est, similis nu-" merorum, an planè e numeris constet oratio: alterum si "sit, intolerabile vitium est; alterum nisi sit, dissipata "et inculta et fluens est oratio. Perspicuum est igitur, "numeris adstrictum orationem esse debere, carere ver-" sibus." In Oratore, 342. 345. 349. Manut. fol.

piece: and it is this excellence which distinguishes the music of a great master from the extravagances of a capricious performer, who has nothing but fancy and execution, without judgment to direct him. Most of the pieces of Corelli, Geminiani, Handel, Martini, Stanley, &c. have a character of their own: their several pieces are distinct and original, so that each is new in respect of the other. But with much music of a modern date this is not the case, because the genius and style of it render it in a great measure incapable of true variety. I heard it first observed of signior Hasse, that when we had heard one of his pieces, we had heard them all. The same observation may now be applied to many authors, when compared with themselves, or with one another. Their style has nothing that distinguishes one piece from another: all is rapid execution and noise; except in the bases, which have neither melody nor contrivance, but surfeit us with the repetition of a few notes, which add but little more signification to the whole than the tabor gives to the whistling of the pipe. The ingenious Mr. Avison, who was himself one of our best composers, very properly compares the present style of music to *bombast* in

in writing, which affects great sound with little sense. He has hit upon the idea of an analogy between the conduct of musical air, and the rules of the prosodia in grammar *.

Rapid execution does well as a matter of curiosity and surprize, when we wish to *see* how far it may be carried; in which case we admire a musician, as we admire a rope-dancer or a fire-eater; but music is intended to charm the ears rather than the eyes. When mere execution is the object, it is destructive of true taste and judgment. "A great part of our fashionable music," says the judicious Dr. Beattie, "seems intended rather to tic-" kle and astonish the hearers, than to in-" spire them with any permanent emotions." And if that be the end of the art, then, to" be sure, this fashionable music is just what" it should be, and the simpler strains of" former ages are good for nothing †." They who travel post through a country, with four horses, and a troop of attendants scampering after them, may give the people an idea of their own importance; but will seldom

* See his Preface to Twelve Organ Concertos, op. 9.

† See his Essay on Poetry and Music, p. 465. The reader will find entertainment and improvement in all the reflections of this learned author upon the subject.

seldom improve themselves or edify others with the observations they make upon the journey. Besides, as moderate wholesome liquors have neither taste nor spirit to those whose palates are vitiated with the practice of dram-drinking; so this appetite for hurry and precipitation has had the unhappy effect of banishing almost entirely that sort of music, with which the mind is most deeply affected. The violent allegros of the age have in a manner expelled the good old adagio, with its deep and sober harmony, from the concert. Surely he is not the best reader who can read fastest. It would appear monstrously absurd, if the eloquence of the pulpit, the bar, or the theatre, were turned into a race; which is now too much the case with our modern music.

The sum of what I have said is this: that there may be nonsense in musical, as truly as in rhetorical or poetical composition; and that it can be avoided only by a due knowledge of measure and method: for which, if no rules are yet laid down in writing, it may be acquired by diligently scoring * the works of the best masters. It is reported

* To *score* music, is to write the several parts of the composition

reported of John Bolton, a learned English divine at the beginning of the last century, that he copied out the whole Iliad of Homer with his own hand, to make himself perfectly acquainted with the Greek accents. Some of his patience is necessary to every musical student who is a candidate for excellence: and if it was generally thought to be necessary that this labour should be submitted to, I am convinced we should have fewer composers and more music.

8. Some Reflections on the Uses and Application of Music.

I cannot dismiss this subject, without reflecting, that although music in practice is calculated to please the ear and move the softer passions, its theory is applicable to some other purposes, and may furnish matter for the improvement of the mind, in two respects.

For, first, it will bear an application to the kindred arts of painting, poetry, sculpture, and

position directly under one another, so that the structure of the whole may be seen at one view. They that wish to hear a full performance of music to the best advantage, should assist their ears by looking upon a copy of the music in score.

and architecture. I shall speak only of the latter of these, because it has probably been less attended to by writers who have attempted to penetrate into the principles of taste. The eye prefers what is rational and commensurable in visible objects, as the ear when it compares musical intervals. Simplicity of ratio will produce a correspondence as agreeable to the sight as to the hearing; and hence the same measures that obtain in music may be transferred to visible objects, as the best that can be invented to produce a pleasing effect *. If I were an architect, I would never fail to try the effect of the musical numbers first in the external face of a building, accommodating the several members and appendages to one another in those proportions. I would observe the same rule within the apartments; not doubting but that the eye would find satisfaction, though it should have no knowledge of the principle from whence that satisfaction arises. Thus, if the length of a room to the breadth and height be as 2 to 1, the ratio is that of the octave;

* See this farther considered in a Letter upon Taste, wherein the proportions of music are applied to composition in painting. Letters from a Tutor to his Pupils, printed for Robinson in Paternoster-row.

octave; if the length to the breadth and height be as 3 to 2, the ratio is that of the diapente, another perfect concord, and the figure will be that of the cube and half. If the length be to the breadth as 3 to 2, and the height to the breadth as 3 to 4, then the height will be to the length as 1 to 2, and we shall have all the ratios of the fifth and fourth and eighth, which constitute a complete system, and will compose a figure perfectly agreeable to the eye. If we reduce this to practice, the numbers may be 24 for the length, 16 for the breadth, and 12 for the height; or any others that have the same proportions. In sacred buildings, the figure of the cross is frequently introduced with a very fine effect: and if across is so proportioned that the breadth is to the length as 2 to 3, in the ratio of the diapente, and the point of transection in the same ratio, the eye will immediately perceive such a figure to be unexceptionable, and perhaps the most beautiful of the kind that can be invented. See plate IV. fig. 8. There would be no end, if we were to apply this principle of harmonic mensuration, as far as it will go, to the different members and ornaments that are introduced in architecture: I must therefore

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be content with leaving the principle to be applied and varied by practical artists, who will certainly find their account in it: and I can make no doubt but that it has occurred already to them, though it is out of my way to inquire after it.

The second use we are to make of music is of a higher kind. All nature may, and therefore all nature should, assist us in acq iring more worthy and sublime ideas of its author. The theory of musical sounds, though adjusted and diversified by the artifice of man, is to be numbered amongst the works of God; whose wisdom originally established the natural measures of harmony, as it appointed the courses of the winds, and the weight of the atmosphere. We should infer from hence, that music is never so properly applied to any subject, as to the praises of the Creator. As it is certainly capable of being made an instrument of virtue, it speaks a language for which it never was intended, when it becomes subservient to the interests of vice and folly. The wise men of heathen antiquity, sensible of the proper use of music, reserved its powers for the instilling of moral instruction into the minds of youth, for celebrating the exploits of their heroes, the histories of their deities,

and

and also for the communication of science*. They were jealous lest the style of their music should be adulterated by the introduction of effeminate airs, and the languid intervals of chromatic melody.

But whatever the Greeks and Romans might pretend to, music never attained its own native perfection, till it was applied in the Trinitarian worship of the Christian Church; as if it had been reserved for that purpose. The abilities of the human mind seemed to be opened and strengthened by the accession of that sublime matter they had to work upon; and devotion, which is falsely called the daughter of ignorance, became the mother of consummate art. It is very remarkable, that, so far as we can discover, Christian

* According to Virgil, the science of astronomy, and the motions of the heavenly bodies, with other articles of natural philosophy, were communicated and celebrated with sounds of music:

——— Citharâ crinitus Iopas
Personat auratâ, docuit quæ maximus Atlas.
Hic canit errantem lunam, solisque labores;
Unde hominum genus et pecudes; unde imber et ignis;
Arcturum, pluviasque hyadas, geminosque triones.
Quid tantum oceano properent se tingere soles
Hyberni, vel quæ tardis mora noctibus obstet.

Æneid. I. 744.

Christian artists were the first persons in the world that invented and practised the method of setting together several parts moving different ways at the same time, yet so as to agree in one design, and constitute one entire harmony: which is one of the finest discoveries upon earth, and is a work of such depth and difficulty, that it never was well done by any, but when it was the result of much learning and labour, and a genius naturally productive of musical sentiment. It has been justly remarked, that the greatest masters of harmony have done the greatest things, and even exceeded themselves, when they composed upon sacred subjects; as if they had been assisted in their studies by some supernatural aid. However that may be, the most excellent music that ever was, or will be, is to be found among the archives of the Christian Church: and of this, amongst other larger pieces, which it is to be hoped the good sense and gratitude of posterity will always preserve, the canon of *Non nobis Domine* is an illustrious instance; and we shall scarcely exceed the truth if we venture to say, that the powers of art and genius united never made so happy an effort in any science whatsoever as in the production of that

that wonderful composition; which I have been hearing for more than thirty years, and still with increasing pleasure and admiration.

So refined and mysterious is the effect of musical concord, that some learned artists have discovered in it an image of the supreme source of all order and harmony. A writer of the last century, who composed a valuable Treatise upon Music, in very elegant Latin, has the following observation: "Nec vacat "mysterio, ternos per intervalla sonos invi-"cem superimpositos, universæ harmoniæ "medullam ac summam ambientis vinculi "nodo nexuque complecti: divinæ illius "monadis triadisque, nutu suo omnia in "ordine pondere et mensurâ gubernantis, "non leve simulachrum; quo nihil ad musicæ "laudem illustrius, nihil excellentius." This passage, in the author's own English, runs thus: "When I farther consider that three "sounds, placed by the interval of a third "one above another, do constitute one entire "harmony, which governs and comprises all "the sounds which by art or imagination "can at once be joined together in musical "concordance; this I cannot but think a "significant emblem of that supreme and "incomprehensible THREE in ONE, govern-

"ing, comprising, and disposing the whole "machine of the world, with all its included "parts, in a most perfect and stupendous har-"mony *." This physical Trinity, as an absolute fact in music, must be evident to every beginner in the science; and it is a Trinity in Unity: but it is a mirror, in which many eyes will discern no image: and I think I have seen this very notion rejected as chimerical by some musical writer of a later date. With me it is a matter of small concern, how such an allusion would be relished by a Middleton, a Bayle, or a Voltaire, whose minds were poisoned by a disaffection to truth. Certain it is, whatever use we may make of the principle, that the compass of all harmony can afford us no more than three sounds in concord, however they may be multiplied by repetitions; and that if they are perfectly in tune, they constitute one sound, which an unpractised ear would find it extremely difficult to decompose. In the harmonics, we have them included within the system of a single note; and in that aerial consonance which was either discovered or observed by Tartini, two concordant notes will generate a third to complete the triplicity of

* Symson's Chelys, or Division-Viol, Part I. § 13.

of the harmony. So apposite is this picture, when compared with the original, that I should be sorry to take the resemblance for the work of chance. And where is the wonder, if nature and revelation, which have the same author, should speak the same language? It would rather be wonderful if they did not. And their language would be better understood, if it were not unhappily the fashion to affect wisdom by rejecting mystery; though the world is so full of it, that the attempt to exclude it is an effort of extreme ignorance. If Mr. Symson's allusion is just, and founded in the nature of things, it teaches us this important truth, that when the praises of the Creator are offered up by the church with sounds of harmony, we pay our tribute to him in that coin which bears his *image* and *superscription*; and thus we render unto God that which is properly his own.

Even Heathens had some obscure glimpse (however they came by it) of a relation between the mystery of music and the mystery of the Deity. Pythagoras, who with his disciples used to take an oath by the figure of a trigon as by a divinity, asserted that God was *number* and *harmony* *. He could

 scarcely

* Τον Θεον εοντα αριθμον και αρμονιην. Lucian. Vit. Auct. The same is related of him by Diogenes Laertius.

scarcely be so absurd as to maintain this doctrine in a literal sense; but must have meant, that there are certain properties in number and harmony symbolical of divinity. The Chaldaic philosophy professed this symbolical wisdom, and taught that the natural world abounds with images of divine truths *. It proceeded so far as to maintain, either in a physical or theological sense, or both, that nature presents us with a Trinity in Unity †.

After all I have said, or can say upon this subject, I must leave it to the meditation of the Christian reader, who is the only proper judge of it; well knowing that it is impossible to recommend a devout sentiment in such terms as shall make it acceptable to an indevout mind. So long as we speculate with the wisest Christians and Heathens, we shall be guilty neither of enthusiasm nor credulity, if, while we are charmed with the sounds of the cathedral, our minds are raised to the contemplation of that mysterious power, from whom all harmony proceeded, and in whom it shall end.

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* *Συμβολα γαρ πατρικος Νοος εσπειρε κατα κοσμον.* See Stanley's Lives of the Philosophers, fol. Part xix.

† *Παντι γαρ εν κοσμω λαμπει Τριας ης Μονας αρχει.* Ibid.

DISCOURSE VII.

On Fossil Bodies, with some Observations introductory to a Theory of the Earth.

Introductory Observations.

THE science of fossils comprehends the knowledge of all those various bodies which are dug from the subterraneous parts of the earth; whether they are such as were naturally formed there, or belonged originally to the animal and vegetable kingdoms, and were deposited there by some change in the course of nature.

I need not say much to prove that the subject is both useful and entertaining, when it is considered, that one of the first universities in the world hath admitted and established a professor, whose department it is to be a guardian and an interpreter of the fossil bodies collected by the late Dr. Woodward; whose merits in this science as a wri-

ter were acknowledged by the most eminent naturalists of his time, and whose labours were encouraged by Sir Isaac Newton himself.

From the earth, the grand repository of fossil bodies, we are supplied with some of the prime necessaries of life; the ornamental arts derive from these the best materials they have to work upon; and the science of physic borrows some of its most powerful remedies: they also furnish matter for operations of the chemist, and open a boundless field for the exercise of his genius.

So far as this science is a spectacle, it will be most entertaining when we come to those figured and extraneous bodies which the earth affords us in such plenty, and which are valued by some curious persons for the rarity of their appearance, and by others for their utility in leading us to many profitable speculations. The examination of all fossil bodies, their situation, their nature, their condition, is absolutely necessary to give us light into the natural history of the earth: inasmuch as no writer will ever be able to strike out any satisfactory theory, without an accurate acquaintance with these things; and it is too true, that some, otherwise very

learned and ingenious men, have been known to err egregiously for want of it: as Dr. Woodward found to his cost, and it gave him a great deal of trouble. If they reasoned about such things as are in the lower parts of the earth, without looking deeper than its surface; we are not to wonder if their speculations and hypotheses were, in the strictest sense of the term, superficial.

Heathen writers were so much at a loss concerning the original and nature of many fossils, that they adopted many strange and fabulous notions. Finding figured stones, and shells, and petrified bones under the earth, and having no rational account to give of them, they supposed them to grow, and breed, and multiply there. Some were called snakes eggs, and many others were called by the general names of *ombriæ*, and *brontiæ*, and *ceraunicæ*, as if they had dropt from the clouds with rain and thunder. Thence the belemnites, and some others that are commonly found, are still called, by the common people of the country, *thunderbolts*. To such a degree had this subject been neglected by men of science, that we hear Merric Casaubon, one of the first scholars and best divines of the last century, repeating the same poor

story. He had got no farther than Pliny and Theophrastus, who believed (or seemed to believe) that stones breed in the earth, and bring forth young ones. He calls all extraneous figured fossils by the vulgar name of *thunder-stones*, and thinks they are owing to *some kind of generation:* appealing to some observations of Wormius, in his Musæum Wormianum, that they engender even whilst stones. He thought it a sufficient proof of this opinion, that some bodies are found with other little ones adhering to them of the same kind, and as it were growing out of them.

In the beginning of the present century, the subject was accurately attended to. The two Scheuchzers, who were brothers, and physicians in Switzerland, pursued it with great assiduity, and began to remonstrate against the absurd opinions which had prevailed concerning the generation, or at least the fortuitous formation, of fossil shells and fish in the earth. Their remonstrances had some effect upon the academicians at Paris, and learned men in all parts began to think the subject more worthy of their examination. It hath been the distinguished privilege of this island to produce the greatest men in every path of science; and about this time, our

our Woodward rose up in England, with talents peculiarly turned to improve and open the philosophy that relates to the theory of the earth. He took advantage of what others had discovered before him; and was furnished with specimens of fossil bodies, not only from all parts of this kingdom, but from many learned foreigners engaged in the same researches: and being a clear and agreeable writer, he was enabled to put his sentiments and discoveries into such a dress as recommended them to the notice of the world. His essay toward a natural history of the earth is very masterly as a composition, exclusive of the curiosity of its matter: and his papers on different subjects, thrown out in consequence of his first essay, and as a farther specimen of his studies, give us such a taste of his abilities, and of the superior lights he had by some means obtained, that no reader can help wishing that the productions of his pen had been more voluminous, and that he had lived to carry on and perfect the inquiries, which he had the gift of explaining in so clear a manner. Every writer who meddles with the science of fossils, will of course be under great obligations to him, which it would be ungrateful to conceal;

ceal; and it is surely owing to the spirit he excited, that the researches of the learned have been carried on with so much diligence, that we have now in this kingdom some of the first collections of fossils in the world. The collection left by Dr. Woodward to the University of Cambridge, has been enlarged by some of the professors. Mr. Lhwyd, a keeper of the Ashmolean Museum at Oxford, made a large collection, which is now preserved in that Museum, and is particularly described in his work called Lithophylacium Britannicum, which has the advantage of some good figures, and consists almost entirely of such bodies as are called *extraneous;* which term will be explained in its proper place. The collection at the British Museum is extensive and magnificent; and though that of Sir Ashton Lever at Leicester-House is one of the last in order of time, it is stored with great variety of fossils, many of them the most valuable in their kinds, and being more accessible, it is better accommodated to give instruction to a curious spectator *.

Most

* My late worthy friend, the Rev. Mr. Alexander Catcott, of Bristol, whose name is occasionally mentioned as it deserves in the subsequent pages, has bequeathed a capital

Most of the countries of Europe have now been searched, and fossil bodies have been brought from all quarters of the globe; of which it is the design of this discourse to give an account: and as the other branches of Natural History have been much improved of late years, it may be supposed that we have now the means in our hands for giving a more satisfactory account of the earth and its contents than hath been heretofore done. The following Discourse is accommodated in a great measure to the fossils in my own private collection; which being neither large nor sumptuous, can pretend to nothing but mere utility. It is not without the utmost diffidence that I undertake to speak of such a variety of things as will come before us, though they have now been familiar to me for several years. Some curious facts I may be able to point out to those who are beginners in this study; and some points which have been thought doubtful may perhaps be confirmed by some new observations. As I would by no means give to our present disquisition the complexion of a controversy, I say nothing at present of the fanciful doctrines

capital collection of fossils to the Library of Bristol, the place of his nativity.

doctrines of Mr. Lhwyd, Dr. Plot, Dr. Lister, and some others, who had no relish for the more rational system adopted and defended by Dr. Woodward, and therefore opposed him in it, adhering to the old superstitious notions of lithospermatic generation, lusus naturæ, and such like.

Having premised these few general observations, in the way of an introduction, I proceed to consider the subject more particularly, according to some natural order and method: not with the hope of exhausting it, but with the desire of selecting such parts as are most useful and important.

Fossils are either *native* or *extraneous.*

The *native* are such as belong naturally to the earth, and are formed in it.

The *extraneous* were lodged there by some accident.

The principal kinds of native fossils are, *earths, stones, gems, minerals* and *metals.*

Among the earths, we have clay, loam, chalk, marle, fuller's earth, bole, &c.

The common black vegetable mould which lies immediately under the turf, is a mixture of salts, oil, or sulphur, water, and pure earth.

Earth abstracted from all other principles, is

is an hard, white, friable substance, not consumable in the fire. It is seldom or never found in its simple state, but may be obtained by burning away all the water, oil, and salts which enter into the composition of a bone; after which nothing but the uninflammable earth remains.

Clay is a tenacious sort of earth, not easily penetrated by water, and therefore it serves an excellent purpose in stopping and detaining the particles of water, and directing them into veins and springs, which would otherwise soak through the lower strata of sand and rubbish, and be lost in the earth. When burned in the fire, it becomes very hard, as a stone, and is either red, white, or yellow, according to the different nature of the clay: by this property it furnishes us with numberless vessels at a small price for the common purposes of life.

Loam is a sort of earth, which partakes of the oiliness of clay, and the richness of vegetable mould.

Chalk is a white substance, which is easily dissolved in vinegar, and will burn into lime.

Marle is a softer kind of chalk.

Fullers-earth is of a pale yellow colour, and of a saponaceous quality, so that it is serviceable

viceable for scouring of woollen cloth, and preparing it for the dyer. It is found in great plenty near Oulney in Buckinghamshire. What they call French chalk, is a brown saponaceous earth, nearly allied to fullers-earth.

To this *yellow ochre* is nearly allied, and is sometimes found of a very bright yellow, among chalk and gravel.

Bole is a red earth, generally in powder, and has such an absorbent quality, together with an astringency, that it becomes useful in medicine, and is applied to several purposes by mechanics.

Of Stones.

These are either, stones properly so called, or pebbles, marbles, slates, talc or selenite, asbestos, the waxen vein, the ætites, and enydros.

Of stones properly so called, the lime-stone is most commonly known, and distinguished by its property of turning into lime when exposed long to the fire *. Other sorts of stone are

* It is a fact so commonly known that we never reflect upon it; but it is a very wonderful thing, that when the moisture of a certain kind of stone, which we call lime-stone, is expelled by fire, the moisture which enters afterwards generates a fermentation which reduces the whole mass into its first principles. *Mirum, aliquid, postquam arserit, accendi aquis.*

are the grind-stone, whet-stone, sand-stone, free-stone, and rag-stone.

Pebbles are either coated, and consist of several involucra, one over the other like an onion; or they consist of layers or plates, and are really rounded fragments from larger masses of stone. Sand in general is composed of a smaller sort of pebbles with a smooth surface. Pebbles are naturally formed on the sea-beach, by the rolling of fragments with the motion of the tides, and their long exposure to the sun and salt water. Marbles, which

aquis. Plin. lib. xxxvi. cap. 23. But this would be of no use, unless the stone, when reduced thus to a paste, would harden into stone again, and become still more and more durable with age. We admire the mortar of the ancients, as if it excelled our own; but it is very probable that it attains this perfect hardness with age. I have observed the walls of Richborough Castle, in Kent, built by the Romans; how large fragments of the walls break off and fall away together like pieces of solid rock; the mortar being full as hard, if not harder, than the stones that were bound together by it. It does not appear from history that there ever was a time when this useful invention of making mortar out of burnt lime-stone was unknown. We may find some traces of it in the origin of languages---*Caleo* and *calidus* seem to be derived from *calx*, lime, because it takes heat: and the Hebrew word for a wall is חומה, from the materials taking heat.

which boys play with, are fragments of Florentine stone, rounded by being rolled in a cask with water.

Some pebbles, such as the Egyptian, are very finely veined, and represent sprigs of trees, landscapes, caverns, and ruins.

Flint is universally in the form of pebbles, or nodules, and generally with a coat which seems to be of harder chalk, as if the flints themselves had been originally formed out of chalk. Sometimes a mass of small pebbles is found cemented together with a flinty substance. Such a mass is called the *calculus compositus*, or plum-pudding stone, and is frequently diversified with a variety of beautiful colours. These bodies were much more in request, till they were of late years displaced by enamel and other fancied compositions of human art. How it should happen that the stony cement should be in a state of solution, while the pebbles invested by it were entire, it may be hard to explain: but so the fact appears; and we observe it in many instances, which make it probable that the earth, even at this day, yields a chemical principle, which, when united to stone, cements the parts together into perfect hardness. The rust of iron, when uniting itself with earthy matter,

matter, has this faculty of giving it a stoney hardness; of which some actual examples were shewn to me by an ingenious and learned member of the Royal Society *.

 The

* Edward King, Esq. Since I saw the petrifications above mentioned, Mr. King has given a very curious account of them, and some others of the same class, in the Philosophical Transactions for the year 1779, which the philosophical reader cannot fail to peruse with pleasure. When we are once possessed of a true principle, it is easy to trace it in a multitude of examples which were not attended to before, though obvious enough in themselves. The petrifying power of a solution of iron upon sand, gravel, and clay, is by no means an uncommon phænomenon; and I wonder it did not occur to me before Mr. King pointed it out. Upon the beach at Harwich, near the water's edge, many tons weight of this sort of petrifaction are to be seen. The smiths throw out their iron slags and cinders from the forge, and lay them in heaps upon the shore, where the sea washes up sand and pebbles upon the iron; and the particles of iron being partly dissolved by the same cause, the gravel, sand and iron unite together into a compound mass of a ferruginеous colour, and the bulk of the iron slags is continually increased; till by degrees, when the intervals between several of these masses are filled up, they concrete together till they form an indissoluble rock of beach and iron.

I have lately been informed of another fact of the same kind, by a friend of mine, who is concerned in an iron foundery for cannon in Wales. He tells me he has frequently seen fragments of iron guns with part of the mold of clay adhering to them, in a state of perfect petrifaction: Also sand, become

The black, white, and dove-coloured marbles are commonly known, and are chiefly brought from Italy. Some of the most valuable sorts are the granite and porphyry: the granite is so called, because it appears like small grains, mixt with another colour which forms the ground. Porphyry is nearly allied to the granite, and has its name from the purple colour of its ground. It is the hardest of all marble; yet antique vases were formed of it, and figured with great art. Its present hardness may be partly owing to its age.

Slates of all kinds are distinguished by their splitting with a regular grain, and sometimes to the utmost degree of thinness. The black slate,

become so hard by its contact with the iron, that it could not be broken off from it but by an hammer.

On the coast of Kent, I have found masses of a stoney hardness, with multitudes of *recent* shells fixed in them; for which I could never account, till I became acquainted with this power of iron in petrifying other fossil substances.

These facts are not only curious in themselves, but they lead us to a new principle which is of great value, and will teach us to compose cements for building, more durable than any hitherto invented, and better able to stand all the attacks of the weather, which will rather strengthen than impair them. We are indebted to the ingenious Mr. King for this hint, in his paper upon the subject; and there are many other observations both learned and useful in the same paper.

slate, when polished, is used for writing. The blue and brown slate is used for covering houses. The method they have of splitting it is this: they expose it in blocks to be well wetted and soaked with the rain; and when the frost comes upon it afterwards, it rarefies the water, and thereby cracks and opens all the joints of the stone; so that when the frost has done its work, it lies in loose flakes or shivers. Thus the elements perform with ease what no manual art could possibly accomplish.

There is a sort of slate in Yorkshire, out of which they extract the salt called alum, by preparing the stone in a particular manner with urine.

The joints of slate, particularly the Irish slate, which is used in medicine, are sometimes figured over with an exudation which disposes itself in the form of trees, or branches, and composes the fossil which is called *dendrites.*

The talc or selenite is found of many different figures; sometimes in rhomboids, sometimes in hexagonal columns: they are generally found in clay, and seem to have been formed out of it, as there are sprigs of clay, not rightly assimilated, found in the middle

of them. This substance is generally transparent, sometimes as fine as glass, and will split into very thin flakes. Windows were formerly glazed with the large rhomboidal selenites split; and thence was derived the form of our ancient diamond panes in glass windows. The selenite burns to a very fine calx, and is used abroad for forming a kind of plaster of Paris.

The *gypsum* is nearly related to the talcs and selenites*; it is called *alabaster*, and vulgarly *plaster*. Sometimes it is hard, white, and opaque, like statuary marble. There is another sort, which is composed of fibres, flakes, or plates, and is transparent. The gypsums are found so frequently in marle, that it seems as if marle were a solution of gypsum, or gypsum a condensation of marle: whence it is well observed by a late author, that gypsum seems to have the same relation to marle, as flint has to chalk. The alabaster, when burnt, makes the finest sort of lime, which we call *plaster of Paris*.

The *asbestos* is so called from its enduring the fire. It appears like hairs or threads, and is capable of being spun and woven into cloth.

* Linnæus calls the selenite *gypsum crystallisatum, figurâ rhomboidali*. Syst. Nat.

cloth. It is supposed that the ancients, who burned their dead, wrapped them up sometimes in a cloth made of this stone, and so preserved their ashes entire for the urn.

The *waxen-vein* is found in nodules of clay-stone, quartered out into *tali* by partitions of a sparry substance, of the colour of bees-wax, which partitions pass through the whole mass of the stone, and penetrate at the same time all such extraneous bodies as happened to be deposited in the matter of the nodule at its formation. The stoney matter of the nodule is of different colours, but in general the partitions or seams which divide it are sparry. The same matter is found in the pipes or worm-holes of petrified wood; and sometimes it is disposed, in the form of stars, between the cavities of the stone.

The *ætites*, or eagle-stone, is a sort of pebble with a cavity, and in that cavity a nucleus which is loose, and rattles within the stone when shaken.

The *enhydros* is another body of the same kind; but, instead of a solid nucleus, it contains water. The Earl of Bute has a stone in a ring, not bigger than a pea, which has a cavity containing a drop of water, which may be seen to fluctuate through the trans-

parency of the stone. It seems to be an agate or white cornelian.

It has been a question with writers on this subject, whether stones grow in the earth: some affirm, others deny it. I never saw any evidence to prove that a pebble buried in the earth is bigger now than it was a thousand years ago. The contrary indeed is plain, from its retaining those marks of attrition upon its surface, which is got by rolling against others in the water, and which it carried with it into the earth when it was deposited there by the waters of the flood. Some stone is reported to be soft with mois ture, and to harden after it is taken out of the earth and exposed to the air; but this is nothing like the growth of a stone. Thus much does indeed appear from the condition of several bodies taken out of the earth, that there is in some parts of the earth a petrifying juice, with which a broken stone will be reconsolidated like a broken limb; and heterogeneous matters, as shells and pebbles, will be fixed into a stony mass.

It was a notion once on foot, that the clay which falls out of the cliffs upon the shore at Harwich, is hardened by degrees, till it changes into the nature of stone. I was once

of

this persuasion myself, and imputed it to the penetration of the salt from the sea-water, and the operation of the sun's heat, alternately taking effect upon the clay. I even powdered some of this stone, and steeped it in pure water, with the expectation of extracting a marine salt; but was disappointed. Some years after, when I had a better opportunity of examining into the nature of this clay, I found that the clay, while lying in the cliff, had all the same appearances which it seemed to have assumed by lying upon the beach; some of it being soft, some hardish, between the nature of clay and stone, and some absolutely hard. I spoke of this to an ingenious gentleman, who had lived many years at Harwich (the late Mr. Davis), who assured me he had observed the same himself, and that the growth of stone upon that shore was entirely a mistake.

Of Gems.

All gems have crystal for their basis; and receive their colour, if they have any, from a tincture of some metal. In some the crystal is finer, in some it is coarser.

There is a substance resembling crystal,

which is found very commonly in stones of different kinds. It is angular and transparent, like crystal; but is known by this difference, that it is soluble in vinegar, or any other acid, while crystal is not so. This substance is called *spar*.

Some spar is angular and pointed; some is disposed in flat plates; some is very large and pointed, called dog-tooth spar; and it has different colours, according to the matter with which it is impregnated.

The finest of all crystals is the diamond, which is generally white, but sometimes of a yellow or straw colour. The ruby is crystal tinged with gold: the sapphire is crystal tinged with copper; and so is the emerald. The yellow topaz, with lead.

Crystals of all sorts are generally found in the cavities and fissures of stones and rocks, adhering to the rock by a base which is called its roof, and rising from thence to different length and thickness; but chiefly retaining the hexagonal form.

Scheuchzer gives us an account of some vast crystals, taken from the summits of the Grimsula, which were of the hexagonal figure, extremely pure and pellucid in their substance; they measured above a yard in circum-

circumference, and the largest weighed two hundred and fifty pounds*.

The handsomest common crystals are brought from Genoa, Norway, &c. We have crystals plentifully in the rock at Bristol, which adhere to a rusty sort of stone, appearing like an iron ore †. Others are found in Cornwall, and others in the North, particularly at Buxton in Derbyshire, and Clitheroe in Lancashire.

There are crystals dug up which appear to have been wrought and polished, probably by the ancient Druids. Some of them are spherical, and some triangular, or nearly approaching to it. They are to be seen in most collections of fossils, and were so plentiful, that it is supposed there was anciently a sort of pebble crystal very commonly found on the surface of the ground in Britain. Dr. Woodward had specimens of different figures, which are now preserved in the Cambridge collection; and I have one myself,

* Phil. Trans. vol. vi. p. [illegible]6.

† In this rock are found balls of crystals, some of them solid, with their points standing outwards. Others are concave, and have their points directed inwards toward the centre. These latter, when perfect, are curious and elegant fossils.

self, which is spherical, about two inches in diameter, and of a very fine polish and transparency. How the Druids could give such a figure and polish to them, is a question we are not able to answer.

There are a sort of stones not so valuable as the crystals, but which, being of a fine texture, and well-coloured, are used in works of art. These are the blood-stone, which is a species of iron ore: the onyx, so called because it has the colour of a nail of the hand. Some onyxes are very finely marked with parallel lines or stripes, and have a transparent ground. The sardonyx is marked like the other, but is of a red colour. The lapis lazuli is of a bright blue, with veins of gold, and is very dear if it is fine. The cornelian is a fine pebble of a flesh colour, but variously tinged, and is sometimes nearly white. The agate is nearly allied to the flint, with clouds of an horny grey colour, and stripes or spots of red, brown, &c. The mocho stone is of the agate kind, and contains sprigs and delineations, which represent moss, within the body of the stone.

Salts and Bitumens.

Salts are found native in the earth: of which

which the most common is the rock-salt, or sal-gem, not differing in its properties from the common sea-salt. Nitre, or salt-petre, is also a production of the earth, and is found in great plenty in the kingdom of Bengal. There is a fossil acid salt, called the acid of the earth, which appears in various forms. If mixed with an oily or bituminous matter, it composes sulphur; if with chalky or stony matter, it composes alum; if with a metallic matter, it becomes vitriol. This salt and iron make green vitriol or copperas; but if it is combined with copper, the colour is blue.

Bitumens seem to be concreted oils of different colours, mixed with an earthy matter; and are generally inflammable. The most common of the solid bitumens is coal; of which the purest kind, and most inflammable, is the cannel or candle-coal, probably so called from its burning with a bright flame so as to supply the place of candles in those countries where it is commonly used.

It has been made a question with some naturalists, whether coal be not petrified wood. That some coal may have been wood is not impossible: and this might account for the grain that is observable in it, and for

the

the leaves and rubbish so often found near it: but the generality of coal is certainly a native fossil body, composed of earth and stone and bitumen.

The most valuable of the bitumens are *jet* and *ambar*. Jet is black, and takes a fine polish. Ambar is yellow, variously clouded, and sometimes contains insects, such as flies, gnats, spiders, within it; whence it once was certainly in a fluid state; as surely as the ice, which contains leaves, sticks, and straws, was a fluid water, in which they floated. Ambar, in the form of pebbles, is found plentifully on the shores of Prussia, near Dantzic; it is also dug out of pits and quarries in the earth. A large revenue is raised from it; the king taking it all as his own property.

Of Minerals.

Minerals are nearly related to metals, being heavy, and of a bright and shining substance; they are also called semi-metals, because they are earths which partake of the nature of metals. Of these, quicksilver is the most remarkable and valuable. It is sometimes found pure in a liquid form, and is called virgin

virgin quicksilver. But commonly it is found in the form of a ponderous earth like red ochre, which is called native cinnabar: from this the fluid mercury is obtained by distillation.

The pyrites is a mineral frequently occuring in England. It is found among the strata of chalk in the form of round nodules, which, when broken, shine like gold and silver, and are radiated from the centre to the surface. Their outer coat is a rusty iron colour. Sometimes this matter is also found in branches or sticks of a cylindric figure. It is found on the shores of Sheepy Island, washed out of the cliff by the tides and storms, and is picked up under the name of copperas. Sometimes it is found combined with the *ludus Helmontii*, or *waxen-vein;* and there is a sort of clay-stone, which has the veins or *septa* of pyrites instead of yellow spar. The pyrites, or fire-stone, is so called from πυρ, *ignis*, because it gives fire, when struck against steel, more copiously than flint.

Marcasite differs from pyrites but little more than in form.

We have said little of sulphur, as a fossil, because it is rarely found in its native form

in the earth; most of what is sold in Europe being factitious, and raised by fire, with a particular process, from the pyrites. I have a specimen of some very pure native sulphur, almost transparent, and of a bright yellow, from Terra del Fuego, in South America: and also some crusts of sulphur, taken out of the mouth of Etna by an English sailor, who dipped the end of his crab-stick into the melted matter. These crusts are tinged in some parts with that sort of red which sulphur takes when melted with an alkaline salt. Whether the sulphur thus raised from Etna is native in the bowels of the mountain, or raised by fire from stores of pyritical matter, can only be conjectured. What is called *sulphur vivum* is the same with native sulphur, and is of different colours, yellow, red, and cineritious.

The lapis calaminaris is a brown earthy substance, like a coarse lime-stone: and is frequently found in the lead mines of Derbyshire. When mixed and melted together with copper, it composes the metal called brass.

Cobalt is not found in England; it is a mineral containing a large quantity of arsenic, besides which it also contains copper and

and silver in a small quantity. Arsenic is found in its simple native state, both of a red and yellow colour: the latter is called *orpiment*, which is a corruption of *auri pigmentum*.

Antimony is another mineral, distinguished from the rest by the shining threads which appear in it, so that it seems like a mass of needles. When melted, it yields a metallic substance, whose surface is always marked with the figure of a star, and is called its regulus. This is used in the composition of pewter, to harden it. When vitrified, it is of great use in medicine; and so is the crude antimony itself, which is given in powder to correct a foulness of the blood, and cure eruptions on the skin.

Bismuth, which is also called tin-glass; and spelter, also called zink, are other minerals, which are used in composition for various purposes.

Black lead is a mineral found in England, and its use is well known. There is a coarse sort of it, which is formed into crucibles, remarkable for bearing the fire very long without cracking.

Of Metals.

Metals are distinguished from the semi-metals or minerals by their weight, their purity, and their malleability. These are gold, silver, copper, iron, tin, and lead.

Gold is found in the form of an opaque ponderous stone of a yellowish colour *, and it is also plentifully found in the form of sand or dust, washed out of mountains by the rains, and sometimes carried into the beds of rivers. Particles of gold are likewise collected from sparry and mineral matter, and from the ores of other metals. There is a sort of clay in Africa, which appears very rich with shining particles of gold, and yet when it comes to be tried, the quantity is too small to make amends for the trouble, so that they form this clay into tobacco pipes.

Silver is found in veins and fissures of the terrestrial strata. Sometimes the disposition of the metallic parts in the ore is such as to represent

* "Heu primus quis fuit ille,
"Auri qui pondera tecti,
"Gemmasque *latere* volentes,
"Pretiosa pericula fodit!" *Boetius.*

represent feathers; sometimes hairs, fibres, or sprigs; and sometimes it is in masses or grains. We have it in England intermixt with the purest and whitest sort of lead ore, some of which will yield a very considerable proportion of silver.

Copper ore is plentifully found in England. Some of it is of a shining blue or green colour, frequently interspersed with a dash of purple, so that the sparry matters which contain it appear extremely brilliant and beautiful. Some think it had the name of Venus given to it by the chemists, from the beautiful appearance of its ore: but it was more probably so called from Cyprus, an island sacred to Venus, where it is found in great plenty.

Iron is found in various forms. The best iron ore appears of a bright colour, with a grain like steel, and is of a good weight. Other inferior sorts are of a darker colour; some brown, some blackish, others ferruginеous, or of a red rusty colour. There is a sort of black sand in America, which yields plenty of iron, and is manufactured to great advantage. The geodes, and bezoar mineral, which are ferruginous stones, coated and globular, are a sort of iron ore. The blood-

stone and load-stone are other species of iron ore.

Tin is a metal no where found in such plenty as in Cornwall. Its name in Greek is Κασσιτερος, whence the British islands were anciently called Cassiterides, when the Phœnicians traded to them for this commodity. The tin grains, as the miners call them, are the richest and best sort of ore. Much of it is found in veins which they call loads; and it is also found in trains, called shoads, which are composed of fragments supposed to have been torn out of the veins by the waters of the deluge, and carried to a distance.

The ore of lead is distinguished by masses of a cubic form. It is found of many colours, white, grey, green, and blue; the latter is the purest, and is found in the mines of Derbyshire, disposed in veins together with the sparry matter of the rocks. Lead is one of the worst of poisons, to which we know of no antidote that can be depended upon. An old miner in Derbyshire, who was washing the purer sort of lead ore in a large wooden vessel, told me, that if either a dog or cat chanced to taste of such water, it infallibly destroyed them. Nay the very smoke

smoke of the furnaces, where the ore is smelted, if blown downwards upon the grass in the fields adjacent, is sufficient to poison the cattle which are feeding upon it. All families should be careful how they use any leaden vessels or machines, especially if the water of their springs is of a corrosive quality.

Of Extraneous Fossils.

Those fossil bodies are called *extraneous*, which are not formed naturally in the earth, but lodged there by some accident.

The learned have made it a question what those bodies are, and how they came to be deposited in the earth? But as we proceed in the examination of the different kinds of extraneous fossils, we shall see many evident proofs, that they were the relics of the antediluvian world, and were conveyed into the strata of the earth by the waters of the flood; which flood was certainly universal, because the remains of bodies belonging to the sea are found upon the highest mountains, and in all the four quarters of the world: but of this we shall speak more particularly in another place.

If we follow the method of Woodward, we

must first examine the remains of the vegetable world.

Fragments of wood are very often found in the strata of the earth. Sometimes they are as hard as stone itself; sometimes more soft, and even friable. The Armenians and Persians have a tradition, that the ark of Noah rested on this or that mountain in their neighbourhood, because fragments of wood are found there turned into stone. That there may be petrified wood in their mountains is easy to be credited, because we have so much of it here; and it is all from the same original. It is all of the same age with Noah's ark, but never made a part of it; because the ark, when stranded after the settlement of the post-diluvian earth, must have been exposed to the air, and consequently must have perished in no great number of years. On the shores of Sheepy Island, in Kent, the best magazine in the world for extraneous fossils, wood is found in great plenty, perforated by different sorts of sea-worms, and perfectly petrified. The tubes or perforations are generally lined with a crust of sparry matter, like that of the common waxen-vein; whence this stone is called *lapis syringoides*, the *piped waxen-vein*. The pipes

pipes are sometimes found with a crust of marcasite, the colours of which are remarkably splendid. And I have one specimen, in which one of the broken pipes, filled with a sparry matter, discovers a perfect and most elegant tooth of some sea-animal; which tooth must have been deposited by some accident in the tube, while it was empty, and the wood in its unpetrified state. I have another specimen, in which the grain of the wood is very discernible; but it is difficult to affirm of what particular kind the wood is. It seems to be either oak, walnut-tree, or mahogany. Many other remains of the vegetable kingdom are found in the same place: I have a fragment of a vine branch, very exactly preserved, and impregnated with a ponderous mineral, which abounds in the soil of the island, and has contributed wonderfully to the preservation of many small and tender bodies. The most remarkable of these are several kinds of fruit, from different parts of the world: such as cocoanuts, which have not only their shell, but also retain the fibrous substance of their husk. Besides these, there are several of the stoned fruits, such as plums, peaches, and cherries, in some of which not only the stone

is distinguishable, but even the fleshy substance of the fruit, embalmed and hardened by the mineral above mentioned*. With these there are specimens of other vegetable bodies, with which we are unacquainted in their natural state, and which were therefore brought from some distant climate. We have here one singular and very curious specimen in the state of a common yellow pebble, which is a petrification of the fruit of the arum. It was found on the top of the chalk-hill of Kent, in the neighbourhood of Sittingbourne, and was given to me by Abraham Tilghman, esq. of Frinstead. See plate V. fig. 1.

In the Isle of Wight, cones of fir, and hazel-nuts,

* Some of these I have represented in plate V. fig. *a*, *b*, *c*, &c. Some have supposed, that the rudiment of what is called the bezoar stone has always a fossil fruit in the centre of it, over which terrestrial matter was collected and formed into coats. Physicians have thought, that the human calculus, which consists of several coats of stony matter, has always some particle or globule of extraneous matter for the first beginning of its formation. A very particular account of the fossil fruits of Sheepy Island was given by Dr. Parsons, with figures, in the fiftieth volume of the Philosophical Transactions, p. 396. Mr. Jacob of Feversham has since added an account of Sheepy fossils to his botanical work.

Plate V. to face P. 134, Vol. 10.

Fig. 2.

a

e

b

zel-nuts, are preserved without petrifaction. They are dug from such a depth, and found in such a state, that we cannot account for them, but by supposing them to be antediluvian; and the people of the place call them *Noah's nuts.* It is certain that the vegetable remains of the flood are not universally petrified; because we find in hard rocks fragments of worm-eaten wood, like that at Sheepy Island, which is in a soft and friable state, and of a ferrugineous colour, like the rotten wood of an old coffin. The marine shells and other bodies, which are found in the same stone with it, demonstrate its antiquity and original. I have seen wood in the same or a softer state from the stone quarries of Harleston in Northamptonshire.

The iron mines afford a sort of nodules which they call *cat-heads.* These, when they are split, discover a plant in the middle of the stone; and if they break kindly, the impression is convex on one of the fragments, and concave on the other. I have one of these, which contains a bearded head of one of the culmiferous grasses, perhaps the wall-barley. The nodule itself seems to be of clay-stone, and the figure of the plant is expressed by a shining steel-grained iron ore.

The plants most commonly found in stone are of the capillary kind, such as the different sorts of ferns, and particularly the *osmunda*, or flowering fern, of which I have a sample. So many kinds of plants are discovered in the strata of the earth, that Scheuchzer, a physician of Zurich in Switzerland, who was eminent in these studies, compiled a *Diluvian Herbal*, exhibiting a great variety of the fossil plants *.

Among many other curious observations relating

* In general, where coal is found, fossil plants occur in the strata that lie immediately over it. A late writer, very conversant in the mines of Derbyshire, makes the following observation: "All the strata incumbent on coal, whether "argillaceous stone or clay, contain figured stones representing a vast variety of vegetables, or the impressions "of them; as reeds of various kinds, striated and jointed "at different distances; the euphorbia of the East Indies, "the American ferns, corn, grass, and many other species "of the vegetable kingdom. They are inclosed in the solid "substance of the stone, &c. These vegetable forms, and "the strata containing them, are the certain indication of "coal, not only in Derbyshire, but in every part of the "kingdom which I have visited: and I am informed that "the same phenomenon holds equally true in every other "part of the world yet explored." Whitehurst's Inquiry into the Original State of the Earth, p. 169.—In general, the stone which holds fossil plants is either very hard and close, or bituminous, so as to give no access to water.

relating to the deluge and its remains, made by himself, and his brother who was equally zealous in these inquiries, he tells us of a trunk of a tree, nine Paris feet in length, with some part of its branches still left upon it, which is lodged upon the highest summit of Mount Stella, the chief of all the Alps of Switzerland, which, according to the barometer, is more than two English statute miles in perpendicular height, and four thousand feet higher than any trees or vegetables are observed to grow. He asks, how it could be lodged there? No art or power of man could convey it; and from the nature of the place it could not possibly be produced there: whence he concludes, that it must have floated upon the waters of the flood, and have been stranded there when they subsided. The place is accessible only to the Alpine hunters who follow the wild goats of the rocks, and to them but at certain times. The brother of John Scheuchzer was so inflamed with the desire of visiting this sacred relic, that he set out in the month of July 1723, under the conduct of some peasants, with a determination to gain the top of Mount Stella, if possible; but when he had travelled with great labour about a mile and half

half upwards into the atmosphere, the snows were then too deep for them to proceed any farther *.

It may be said, that fossil plants are no more than accidental lineaments in the stone; but they answer so exactly to the lineaments of nature, that they must have been derived from the real bodies. We have a mass of fossil plants from a coal mine near Bristol, in which it is evident that the leaves were real: for some are doubled backwards and folded over others of a different sort; which could not have happened, if they were no more than accidental figures on the stone. Many instances of the like sort may be seen by any curious person who will inspect the fine collection of fossil plants in the Museum of Sir Ashton Lever, at Leicester-House.

The *dendrites*, which is an imitation of sprigs

* See Scheuch. Herbar. Diluv. p. 56, 57. "When we "find on any of these stones an exact resemblance of a plant, "a leaf, or some fruit that we are acquainted with, if these "leaves are *bent*, or *folded*, if they *cross each other*, or lie "one upon another, these are certain indications that the "plant or fruit so represented is an impression made by a "natural body." Le Pluche, Spect. de la Nat. Dial. 25. We have a specimen in which a thin leaf of the potamogeiton lies over a leaf of fern, so that the flexures and prints of the fern which is underneath are seen through it.

sprigs and mosses in slate, never exhibits any thing of this kind. Petrified sea-shells are sometimes marked with the impressions of sea-plants.

Of Coralloids.

There is a sort of bodies growing in the sea, and generally adhering to rocks, which go under the name of *corals*. They are of various figures, colours, and dimensions; but are of a stony consistence, and for the most part affect a branched form. Before these bodies were so well understood as they are at present, they were classed with vegetables, and reckoned among the submarine plants: but it has been discovered of late years, that they are animals of the polype tribe. The ingenious Mr. Ellis demonstrated their original by several experiments, particularly by burning a branch of coral in the fire; with which it betrays the smell of an animal oil, and is thereby distinguished from the whole vegetable kingdom. Dr. Woodward was very much at a loss to account for the preservation of corals at the deluge, when all stony matter was dissolved: but if corals are constructed as animal substances, it is less

less to be wondered at, that they were preserved, when common stones were dissolved.

These bodies are very frequently found in a fossil state, and so well preserved, that it is hard to distinguish some of them from the natural bodies; but the difference is shewn by examining the specific gravity, some fossils being to their correspondent natural bodies as 279 to 246. The fossil bodies are heavier than the natural, by being impregnated with stony particles. We have tried the experiment on the natural and fossil *mycetites;* a species of coralline fungus in the form of a cone. Specimens of this body are found in Essex, of the colour and substance of a yellow pebble: sometimes they are inclosed in flint, of which instances occur to us in Kent, on the chalk-hill; and there are some very remarkable specimens from Stockton, in Wiltshire.

The *astroites* is a fossil marked on the surface with stars, and is of a stony, sparry, or flinty consistence, according to the bed in which it happened to be deposited. If the flint is broken which encloses it, the branches of the coral may be very plainly traced, and they are of a colour much whiter than the flint. The small astroites is sometimes very

very elegant, and those of flint look well when they are cut transversely and polished. When the astroites was in its natural state, every concavity on the surface was the nest of an animal of the polypus kind. In Derbyshire there is a sort of coral found, which is striated on the outside, and divided into partitions within by transverse plates or diaphragms. It is very usual to see many sections of these bodies in the marble of the Peak; some of which are cylindrical, and others inclining to an oval.

The corals in general are distinguished by a radiated cavity; and in many specimens of the tubular coral, the cavities are not filled up with the stony matter in which they are found. From Minorca we have a sort of coral, which stands in pillars upon a flat base, and is found only in the fossil state. We have another sort of coralloids, which are called *fungitæ*, from their resemblance to a mushroom: in some of these the gills point upwards, and in others downwards, as in the natural kinds. Of those with the gills upwards, numberless specimens occur on Bullington-green, near Oxford; but they are of a coarse and ordinary stone.

Dr. Plott objected to the fossil *fungi*, as bodies

ocean can never be explored by man, nor exposed but by some catastrophe which subverts the globe, it is by no means improbable that the sea is stored with them at this day. Reason indeed must assure us, that many strange bodies exist in unfathomable seas, which no accident less than some convulsive change in nature can discover to us in their natural state.

Some specimens of the entrochus seem to have consisted originally of two concentric parts, an axis, and a cylinder investing it; the former like a male screw, composed of lenticular plates joined together; the latter like a female screw, with cavities adapted to the processes of the axis. No art of man could separate these, because every one of the threads is separately locked into its corresponding cavity; yet they are frequently found separate. In the Peak-marble we see the investient cylinder with a cavity in the place of the axis; and in the stone of Staffordshire the axis is found divested of its cylinder. Dr. Plot, in his History of Staffordshire, calls these *screw-stones*, and has figured them very exactly. It is hard to account for this phænomenon, unless we suppose the axis and cylinder to have consisted of different

ent materials, so that the one might be dissolved and perish, while the other was preserved.

The single joint of the asteriæ will move about in a saucer, if immerged in vinegar: but so will any other calcareous body of a proper form, if it is rendered buoyant like the asteriæ, by the bubbles of air excited in it by the operation of the menstruum.

Of Fossil Sea Shells.

The shells of sea-fish are of various constructions, but are reducible to the two grand divisions of *univalvular* and *bivalvular*; the former of which consist only of a single shell, the latter have two; and these in some sorts are equally matched, in others they are unequal.

Of the *univalvular*, the most simple is the tube of the sea-worm, which occurs of many sorts and sizes in the fossil state: some of them are nearly straight, as those of the *lapis syringoides*, or piped-waxen-vein, and others very much intorted. They are very frequently found adhering to some fossil sea-shell of the bivalvular kind; and this adhesion demonstrates the actual marine origin

of both bodies; for thus we find worm-tubes attached to oyster shells and other productions of the sea, which we take from the shore.

Of Turbinated and Spiral Shells.

The univalvular shells next in order are those which are regularly turned: of these the varieties are very extensive; some are both twisted and drawn out into length, as the *buccinum*, or *whilk-shell*; the *cochlea*, or *periwinkle*; and many more of kin to them. Others are likewise regularly intorted or spiral, but they lie in the same plane, and are divided into many chambers by thin testaceous plates, in the manner of diaphragms, which are perforated with a small hole, that there may be a communication between all the chambers. The most remarkable of this kind are the *nautilus*, and the *cornu ammonis*: which latter was so called, because it resembles the ram's horns which were anciently affixed to the statues of Jupiter Ammon; and there is one species of the natural cornu ammonis, (the only one that occurs,) which has exactly the form of a common ram's horn.

Many turbinated shells of the whilk-kind are

are taken out of gravel-pits, stone-quarries, and clay or marle-pits in great abundance, and in such preservation, that it is sometimes difficult for the eye to distinguish between the fossil shell and the natural.

Three different Conditions of Petrified Shells.

Here it may be proper to observe, before we proceed farther, that there are three different conditions in which these fossil bodies are found. The shells are either empty, as when they are found thrown upon the shores of the sea, or they are filled up with stony, flinty, chalky, earthy, and sometimes crystalline or sparry matter; or, (which very commonly happens,) the stone or earth is found in the figure of a shell, while the shell itself, which served as the mould whereinto the matter was cast, is entirely lost, either by age, fracture, or dissolution.

These casts, in the form of sea-shells, have been considered by some naturalists as mere imitations, which never had any relation to the shells of the deluge: but these bodies are so far om affording any objection against the common evidences of the flood, that they speak the same language with all the other

remains of it; for, by what accident soever the investient shells may have been lost, which we are not obliged to account for, it is certain these casts all had a shell once upon them, because they are not marked with the *external*, but with the *internal lineaments* of the shell which they represent. The bullet takes the figure of the cavity, never that of the external parts of the mould; and whatever scratches or irregularities the cavity may have, the lead will take them all off exactly. If we allow it possible, that lead, which affects a cubic form, might be taken out of the earth in a spherical figure, like that of a bullet, yet nature could never be expected to mark its surface with the strokes of the tool that gave a figure to its mould. A cast thus marked with the internal lineaments of a sea-shell, is a curious phænomenon in natural history; and from it we have these three inferences: 1. That the matter of the cast was invested with a real shell; and in masses of the echinitæ found in flint, the exact space once occupied by the shell, is left vacant in the flint*. 2. That the matter was fluid when

* Such specimens, with the space of the shell left vacant, are common in the chalk-hill of Kent; and some fine ones of this sort are to be seen in Sir Ashton Lever's Museum.

when it entered; because it could not otherwise have taken the lineaments which it so minutely expresses. 3. That if the stone we find within the shells of the deluge was fluid, the stone without them was fluid also; whence it is the less to be wondered at, that we find masses of all kinds of sea-shells imbedded in chalk, stone, marble, and even flint itself.

Mr. Da Costa has a learned remark, that some fossil casts were "not immediately "moulded in the shells, but were formed in "cavities, which those shells formerly filled "in the rocks they were lodged in; these "rocks being of a loosened texture, and "the water continually pervading them, rot-"ed and destroyed the inclosed shells, and "bore away their whole substance, and af-"terwards replaced stony particles into those "very cavities which the shells formerly "filled, consequently these bodies were "moulded exactly to the said cavities." Phil. Trans. Abr. vol. x. p. 637. In such cases the stone will have taken the *external marks*, contrary to what has commonly happened.

Heterostropha.

A singular circumstance is observable in some turbinated fossil shells. In the natural shells which are turbinated, from the common periwinkle up to the Patagonian *buccinum*, the orifice of the shell, when presented towards us, is still on the left side of the shell, and the cavity turns about to the right; but in many fossil specimens, some of which I have collected myself from the cliff at Harwich, in Essex, the orifice is on the right side, and the cavity turns about to the left; they are therefore called *heterostropha*. Many natural shells of this form may exist somewhere in the world; but I never remember to have met with more than one; and that is a large *buccinum* preserved in a drawer of a cabinet of the Ashmolean Museum at Oxford.

Of the Fossil Nautilus.

Several varieties of the *nautilus* are taken from the earth in England, though none are ever found in our seas: they are common in the East Indies, and are found also in the Mediterranean; the largest of them is called the

the *Nautilus Græcorum.* Very fine specimens of this shell are found inclosed in the vast nodules of the *ludus helmontii,* which fall upon the shore from the cliffs of Sheepy Island in Kent. They are sometimes extracted very fair and large, and are called by the labouring people of that place, sea-eggs, because the shell is become white and earthy with age, so that it has much the appearance of an egg-shell, and toward the central parts it has something of the shape of an egg. This fossil is sometimes in such preservation, that the native polish and pearly hue are still retained upon it. When this shell is found lodged in the waxen vein, a phænomenon is observable in some of the specimens, which seems the most surprising and unaccountable of any that occurs in this branch of philosophy. The stone is quartered irregularly into tali or cubes, by seams of a coarse yellow spar, of the colour of bees-wax, which intersect the stone in many directions; and what is wonderful to see, these seams of spar pursue their course through the substance of the nautilus, as if nothing had been interposed, though the shell is nearly as impenetrable as a flint.

The case is very difficult, if we consider it as a penetration of the shell; but, perhaps, when the shell was detained within the stone, it was obliged to part and crack by the subsequent shrinking of the stone; so that when the spar filled the seams of the stone, it filled up the crevices of the shell at the same time. The insinuation of the spar through the *siphunculus*, and its forming a column within the chambers of the shell, is another remarkable circumstance. Upon the whole, the nautilus, thus inclosed and affected by the waxen-vein, is one of the most curious fossils in the world.

Large specimens of the *mailed nautilus* are found in the rocks of the hill at Pluckley in Kent, in which the *septa* and *siphunculus* are distinguishable. One specimen I had from thence, of a large paper nautilus in a kind of sand-stone, which I gave to Sir Ashton Lever. A fragment from thence of a cast of the great mailed nautilus, is impressed with the tubes of sea worms, which shew that the shell was what we call a dead shell, that is, without a fish in it, at the time of the flood, these worms having got possession of its *inside*. The small mailed nautilus is found

found of a brassy hue in Sheepy Island, being impregnated with the copperas mineral of that soil.

OF THE CORNU AMMONIS.

This shell, in its form and construction, is nearly allied to the *nautilus*, and has been described already, so far as is necessary to our purpose. It is remarkable that although so many varieties are found in the earth, and of all sizes, from a quarter of an inch in diameter to two feet or upwards, only one sort has been taken fresh from the water, and that not an inch in diameter, from some fresh water in the island of Barbadoes. Whence it will be inferred, that this noble shell, the glory of the ocean, has either been lost to the animal kingdom since the deluge; or that it is an inhabitant of the deepest seas, where no storms can reach to disturb it and expose it on the shore to human observation. If this latter is the case, which is most probable, then the abounding of these shells in the strata of the earth, and that in countries most remote from the sea, is a proof that the ocean has been disturbed from its bottom; and that its contents, which were once inaccessible,

cessible, have been every where thrown out and intermixt with the land: an effect which no partial inundation, nothing less than a power which operated from beneath the very roots of the sea, can account for.

It would be endless to describe the many varieties of this fossil. The most remarkable for their elegance are those in which the lineaments of the foliated diaphragms are visible on the outside; the inflexions of which within the shell are also extremely beautiful; and in some of these shells the pearly substance, and the glorious colours of it, are still preserved*. In very many instances the shell itself is perished, and the casts are of various matter: many large ones are of limestone, and are common near Bath: some of a blackish stone, very fine, are taken from Colebrook-Dale in Shropshire: some are of copperas, with the chambers and siphunculus open and distinct†. A very small and tender sort of ammonite, with the shell still perfect, and the chambers filled with a shining mineral, is taken in great abundance from

* Two very fine specimens, with the shelly substance remaining, are to be seen in Sir Ashton Lever's Museum.

† I have one of this kind from a clay-pit at Kettering in Northamptonshire.

from the clay pit of Shotover Hill, near Oxford. Many elegant ones of a middle size are inclosed in nodules of clay-stone about the cliffs at Scarborough in Yorkshire. It was the fashion anciently to call these bodies *snake-stones*. The island of Malta has long been celebrated for them, where they passed for petrified serpents; all the snakes of the island having been turned into stone, as the legend goes, for the sake of that which bit St. Paul: and some authors affirm that they have been found with heads on, with teeth and eyes in them. Our Camden says they are found in round nodules of stone like cannon bullets, upon the shore at Huntley Nabb near Huntscliffe, not far from Gisburgh in the North Riding of Yorkshire, at the foot of the rocks; and observes, that they are *generally without heads**. The art of man, however, has employed itself very ridiculously in carving snakes heads upon them

* Ad Huntly Nab littus, quod longo tractu jacuit apertum, in cautes celsius surgit, & sparsim ad earum radices jacent saxa, variâ magnitudine tam affabre sphærica figura a natura efformata, ut globi artificis manu in majorum tormentorum usum tornati videantur. In quibus effractis inveniuntur *serpentes saxei* suis spiris revoluti, sed qui plerique *capitibus destituti*. Camd. Britan. Ann. 1607, p. 586.

them with teeth and eyes, of which I have seen some examples in the cabinets of the curious. It answers much better to slit them through the middle into two parallel planes, for thus the chambers and elegant partitions of the shell are exposed to view; and if they happen to be filled with extraneous matter, which will take a polish, they appear very distinct and beautiful.

Some fossil shells of the *cornu ammonis* having lost both the outside covering and the diaphragms, after they were filled with spar, the chambers, with all their curious articulations, become separable, like the joints of the vertebræ of an animal *, which may be applied again to each other like the bones of a skeleton. This curious fossil was first described by Mr. Baker, F. R. S. who had received it from Dr. Miles. He has given a figure of it; and rightly conjectured that these vertebræ were joints of spar formed in the chambers of an ammonite. See Phil. Trans. Abr. vol. x. p. 641.

OF

* A set of these fossil vertebræ from Oxfordshire were given to me by my dear and much-lamented friend, the Rev. Samuel Massingberd, late a Fellow of Magdalen College in Oxford; who was so unfortunately lost when the Augusta man of war was burnt in the river Delawar in America.

Of the Orthoceratites and Belemnite.

There is another extraordinary fossil shell not commonly found, which resembles the nautilus and the cornu ammonis in having the like concamerations; but it differs from them in this respect, that whereas they are turned into spires, or turbinated, this is perfectly straight and cylindrical, tapering regularly toward the smaller extremity. It is generally about a foot in length, and an inch in diameter. A fair specimen of this fossil is in the possession of the ingenious Mr. Latham of Dartford in Kent, who observed it in a slab of stone belonging to some pavement in that neighbourhood *. Many more are to be seen in the stone pavement laid down of late years in the hall of University College in Oxford. Though there is no doubt to be made that the fossil orthoceratites is a body of marine origin, no recent ones have as yet been discovered. A marine animal nearly allied to it, is the chambered worm, which has lately been found in the natural state in a ship's

* He afterwards presented it to Sir Ashton Lever for his Museum.

ship's bottom, and was shewn to me by a gentleman at Sheerness. A stone full of the chambered worm has been brought from Holy Island in Scotland.

No kind of fossil body has occasioned more speculation than the *belemnite.* When a spirit of ignorant credulity prevailed more than a spirit of rational inquiry, these stones obtained their name because they were supposed to be bolts dropt from the clouds in a storm of thunder; whence, the vulgar people, in some places where they are common, still call them by the name of *thunder-bolts.* In shape they are much like the straight nautilus which we have been describing, taper cones: they appear to the eye as if they were of a middle nature between flint and horn, and they calcine to a white powder in the fire like a sea shell. At their base or larger end we find a conical cavity, which is generally empty, or filled up with stone or earth, according to their situation: but in the more perfect ones, this cavity contains a sharp-pointed conical body called an *alveolus*, which consists of transverse plates, so near together that the outside is marked with rings, and the intervals between the plates are very small. From the point of the internal cone, a central line

or

or axis is produced down the solid body of the belemnite, and lines are drawn from this axis to the circumference of the external cone, so that when it is broken transversely, it exhibits the area of a circle with its centre and radii. It is evident from several circumstances, that this body belonged originally to the sea. For, first, it is found in gravel-pits or stone-pits, among a variety of other productions of the sea. Secondly, it has been found with tubes of sea-worms adhering to it, of which an ingenious gentleman has taken notice in the Philosophical Transactions *. Thirdly, its *alveolus*, in its substance, its testaceous polish, and the concavity of its septa or transverse plates, has a very near affinity to the cylindric nautilus; and I think I have observed some specimens with the hole of the siphunculus, or pipe which makes a communication between the chambers of the shell †. On these considerations

* A very valuable specimen of this kind, with a mass of worm tubes adhering to its outside, was presented to me by the Rev. Mr. Price, of Wadham College in Oxford.

† I examined several specimens critically with a magnifying glass, assisted by a learned gentleman familiarly acquainted with all the branches of natural history, (Sir Henry Inglefield,) and we were clear that the alveolus has a siphunculus very near its margin.

ations we suppose the alveolus, like the orthoceratites, to have been the testaceous receptacle of a fish, or some marine animal nearly related to the chambered worm. What purpose could be answered by that vast heavy testaceous sheath which incloses the alveolus, it is hard to conjecture, because we have had no opportunity of making any observations on its mode of subsistence; whether it adhered by its base to a rock, as the muscle fastens itself by its fibres, or was inserted by its p int into some socket, as the sea-worm which buries itself in extraneous matter, or the *pholas*, which by a rotation makes a hole (like that made by a centre-bit) in chalk or stone, wherein it lies concealed. It could not have been an appendix to some other shell, like the spines of the echinus, as I once imagined. The phænomena of its alveolus do by no means agree with this; and the magnitude contradicts it; some belemnites having been found nearly as thick as a man's arm, of which one example was shewn to me by Charles Grey, Esq. of Colchester.

A small transparent kind of belemnite, which tapers toward each extremity, and is called *fusiform*, from its resemblance to a spindle,

spindle, is found in clay-pits in many parts of England. I had some of them from a clay-pit appertaining to a tile-kiln near Charing in Kent.

Of Bivalvular Fossil Shells.

As it is not my design to give a natural history of sea-shells, I must not attempt to describe the many kinds of bivalves which occur to us as fossils; but shall select a few of those which are most to our purpose, as being either curious in themselves, or giving occasion to some useful remarks. If a more accurate history of shells be required than can here be delivered, it may be obtained from Dr. Lister's figures; as also from a French author, who has given elegant engravings; and from Mr. Brander's work lately published. The finest shells that ever were figured, are to be seen in a folio book, one copy of which was presented to the University Library at Cambridge by the King of Denmark, and another to the University of Oxford.

There was a time when several learned men, some of simplicity, and some of design, made it a question whether fossil shells were really of marine extraction: but we have al-

ready seen some proofs of it, and it is now so generally allowed among naturalists that it is scarcely worth while to insist upon it. However, to give all possible satisfaction in a question so curious and important, I shall offer one argument, which is taken from an inspection of the fossil oyster.

The shells we find in the earth must have been marine shells, if they ever contained a fish; for certainly fish could never subsist in the bowels of the earth. Now, if we examine any proper specimen of a single fossil oyster shell, we shall plainly distinguish what is called the rock, that is, the rudiment of the cartilage by which the oyster was fastened to the shell. If the shell had the ligament, it had the fish; and if it had the fish, it was once in the sea, as those we now take from the shores.

Very fine fossil oysters, with both valves, many of them seeming to have been compressed and flattened with an incumbent weight, are found at a great depth in the clay-pits of Shotover Hill, and in all the clay of the parish of St. Clement's at Oxford. They are also taken very fair and perfect from the lime-stone rock of the hill near Pluckley in Kent. In the quarries near Leeds, in the same

same county, they are of a vast size, to eight or nine inches in diameter, and proportionably deep, with both their shells entire, and united as when alive. One of the largest was given to me by the Honourable Mr. Fairfax of Leeds Castle.

There is a sort of oyster called the *ostrea arborea*, or tree oyster, because it fastens itself to branches or twigs which hang into the water. Dr. Woodward says, they are found on the twigs of the mangrove trees on the shores of Jamaica. Very perfect ones of this kind, with the cavities which shew that they once adhered to branches of trees, are taken from Shotover Hill; and some have been found in Pluckley Hill in Kent.

An oyster shell of a very particular figure, which Dr. Woodward calls *ostrea figurâ oblongâ rostro longo recurvo*, which in English is the *crooked-billed oyster*, is very common on ploughed lands in some parts of Northamptonshire. The larger shell is often found alone; but some samples have the *operculum* complete. Very fine ones of this kind are brought from Bath, and the places adjacent. Some call this fossil by the name of *gryphites*.

Small fossil oysters, nearly in the shape of an ear, which sort I believe rarely if ever oc-

curs in our seas, are found in such abundance in the inland counties of England, that I observed a stratum of them, near a foot in thickness, and three or four feet below the surface of the earth, which extends through the country, for a tract of twenty or thirty miles, in Northamptonshire and Bedfordshire.

The fossil bivalve most considerable after the oyster, because it occurs in so many different forms, is the *concha anomia*. It differs from those of the scallop and cockle kinds, in having one shell which projects with its beak over the other: and in the beak of many there is a circular cavity; which gave Dr. Morton, the natural historiographer of Northamptonshire, occasion to call it by the name of *terebratula*. These occur in vast multitudes, and in great pefection, both smooth and striated. I have extracted large quantities of them from stone-quarries in Northamptonshire.

Fossil Shells bored by the Purpura.

But I met with one from the chalk-hill near Thurnham in Kent, which merits a particular description. There is a fish, of the turbinated kind, which is called the *purpura*. This fish has a faculty of extending a *proboscis*, with which it bores an hole, exactly round,

round, thr. ugh the shell of some small shell-fish, and thence sucks the fish for its nourishment, or destroys it so that it no longer has the power of closing its shell against an enemy *. The small *concha anomia* above mentioned has this perforation so exactly circular that it must have been mechanically produced by the tool of the *purpura.* The inference is obvious, that a shell thus perforated must have had a living fish within it †.

These *anomiæ* were once thought questionable as to their origin, because the seas afforded us no recent shells of the same sort to match with and authenticate them.

Anomiæ found recent.

But a farther inquiry has discovered several of them. The British Museum has one perfect specimen of the recent black smooth *concha anomia,* which is so great a rarity that it has been valued at some hundreds of pounds.

* Lingua purpuræ longitudine digitali, qua pascitur perforando reliqua conchylia: tanta duritia aculeo est. Plin. lib. ix. cap. 36. This is the fish from which the ancients extracted their scarlet dye.

† Many fair specimens of fossil shells thus bored by the purpura, were shewn to me in the Woodwardian Collection at Cambridge, by Mr. Green the present professor.

pounds. Linnæus was said to be possessed of the only one extant besides, and that not so perfect as this. The white concha anomia, both smooth and striated, is now brought from the Mediterranean, and one of each sort was shewn to me some years ago by Ingham Foster, esq. merchant of London, a gentleman very curious in collecting, preserving, and arranging fossil bodies, the most perfect and valuable in their several kinds.

Extraordinary State of some Fossil Shells.

In some fossil shells of the bivalve kinds, these three things are observable: first, that some are found in a particular soil, which have an appearance as if they had been half roasted or calcined; while others perhaps have been entirely consumed and destroyed in vast quantities by the same cause. It has occurred to me, that possibly some parts of the earth, where there was a mixture of vitriolic and sulphureous principles, may have taken heat during the settlement of the strata after the flood till the fermentation at length subsided, when the contending principles were duly intermixt. The same kind of principles which generate the fire of a volcano, may have operated in a lesser degree in some places, so as to

to account for the phænomenon here alluded to. The shells affected in this manner are found in earth abounding with crustated stones of a rusty ferrugineous hue, or yellow brownish colour, of which there are many strata in some parts of Northamptonshire.

The second thing observable is, that many bivalve shells, as cockles, muscles, &c. though they still adhere together by their beaks, are gaping and wide open; sometimes totally separated, but yet lying near together: whence we collect, that the fish was gone at the time when the shells were inveloped with terrestrial matter, and that these were what we call *dead ſhells*, such as we now find lying in the ouse or mud of the sea shore.

Thirdly, that many are found fractured and squeezed, some entirely flat, by the incumbent weight of the strata which settled upon them. A gentleman informed me, he met with a quarry, in Gloucestershire, abounding with the *striated anomiæ*, wherein every shell that occurred was thus affected. The reason of which might be this, that the matter being not fluid enough to penetrate and fill the cavity of these shells, there was no counterbalance within to sustain the pressure

from without, when the earth shrunk in upon them and compressed them.

Among the bivalves, two other sorts occur in the fossil state, which deserve to be mentioned for their singularity; these are, the *Noah's ark*, and the *Horse-head*.

Arca Noæ.

The Noah's ark is a shell allied to those of the muscle kind. The valves of it, when they are joined together, are so formed as to represent a boat with a deck to it. A species of this shell, fluted after the manner of that which is called the *harp*, occurs in most of the stone quarries between Maidstone and Ashford in Kent, which are very numerous. The testaceous substance of the shell is perished in every instance I have met with, and nothing remains but the cast; and even that is sometimes so compressed as to be reduced to a mere impression upon a plain surface, like the leaves of a fossil plant. I was long in doubt what this impression might be referred to; but at length I recovered one specimen, of the natural bulk, with its figure complete, which is very singular and curious.

Horse-head.

The *hippocephaloides*, which is so called because it resembles the figure of a horse's head, is a kind of cockle, depressed on one side, and having the suture or joint in the middle of the depressed part. It occurs only as a cast, without the shell, and is of stone or flint. In a quarry of Buckinghamshire it is found of lime-stone, very finely powdered over with the shining particles of the marcasite; many samples of which were sent to me by Sir J. Van Hattem.

Of the Echini and Echinitæ.

The *echinus*, or sea hedge-hog, is a tender and elegant shell, variously shaped, and has other little shells accommodated to it, for which reason it is not reckoned among the univalvular. It is armed with prickles or spines, some pointed, some very obtuse, and many of them are adorned with tubercles which give them something of the appearance of a Gothic turret. All the spines have this property, that the grain crosses them obliquely, nearly at an angle of forty-five degrees to their axis, (I believe most exactly

so,)

so,) and they always break in this direction. The shell also is composed of exceeding fine laminæ, splendid like the plates of talc; and their grain is disposed at the same angle with their surface. Some of these spines are brought from the countries about the Levant, and figured like the fruit of the olive. They were formerly used in medicine by the name of the *lapis Judaicus*, when it was the fashion to introduce gems and other fossil bodies into the *materia medica.*

The structure of this shell is highly artificial and elegant. The parts are indented together by hexagonal sutures, of which we shall hereafter see the marks very plainly in those casts of flint and stone which have taken the internal lineaments of this shell.

The sorts of fossil echini have been distinguished by names alluding to what their figure is thought to represent. There is the *echinus cordatus*, which is fashioned like a heart: the *galeatus*, which is like the crown of a helmet, or rather like the human skull: the *pileatus*, pointed like the crown of a hat, or like a sugar loaf: the *mammillaris*, so called from those remarkable tubercles, like nipples, which are the roots whereto their spines were fastened, but from which they are

are generally broken off by the accidents to which they were exposed, either before or at the time of their lodgement in the strata of the earth. To these we must add the *echinus pentaphylloides*; as remarkable as any: it is very large, and has the figure of a flower with five petals inscribed upon the crown of it. There are so many intermediate sorts of echinus variously compounded of those I have mentioned, that it is hard to say where one sort ends and another begins.

The *echinus* fashioned like an heart is very common in gravel-pits, and (but for the figure of it) appearing in all respects like a common pebble. Vast numbers are to be found among the flint-stones of Epsom-Downs, where they frequently go with their fellow-pebbles to the mending of the roads. They are also found in great plenty among the flint-stones of the Chiltern-Hills, and I believe in every branch of the Chiltern throughout the kingdom. The natural echinus of this figure is frequently picked up on the sea shores, so that we have the opportunity of comparing its signatures with those of the fossil kind. As most of the shells of the echinus are very tender, and some of them exceedingly thin, we find the fossil echini fractured

fractured and shattered in every way that can be imagined; insomuch that we shall see many casts of this shell, though consisting of the hardest flint, yet as much distorted as a mass of soft paste would be, if it were inclosed in wafer-paper, and crushed violently together with the hand. The *echinus galeatus* exhibits the like phænomena, which are by no means peculiar to the sort last mentioned. It is often found as a detached pebble, and sometimes bedded within a mass of flint. The chalk of the Kentish hills affords a great variety of the different sorts of echini, some filled with chalk, others with flint, and many of them in very fine preservation. I have never yet heard that the conical echinus, which Woodward calls *pileatus* and *conoides*, has been discovered as a natural shell upon the shores in any quarter of the globe. The *echinus ovarius*, with large *papillæ* upon it, and thence by some termed *mammillary*, is to be met with as a natural shell, and when perfect is extremely elegant and valuable. Some echini found on our own shores tally very exactly with those of chalk or flint, which have been taken from the chalk-pits of Kent, at Greenhithe, Northfleet, and Dartford. When those with the largest papillæ

pillæ are perfect, or nearly so, they are highly esteemed as capital curiosities of the fossil kind; and the workmen are so well acquainted with their value, that they sell at a very high price, even when they are bought at the pits. This rare echinus has been found in flint and in chalk with many of its spines adhering to it; some elegant specimens of which are shewn to his friends by the ingenious Mr. Latham of Dartford..

There is a smaller sort of the mammillary echinus, about the size of a coat-button; and, being nearly of the shape of some button-molds of the old fashion, it has been called *fibularis*. It has been found in many places, but we have met with it in the greatest perfection among the rubble earth of a limestone quarry in Orlingbury-field in Northamptonshire: and it was observed by a friend, that they generally lie edge-wise in the earth, so as a body of this figure would naturally sink in water in that posture where it met with least resistance from the fluid. The shell itself is finely preserved in these, and with some of them the fractured spines are found adhering in masses to the bottom of the shell. They agree very minutely with the small white echini which are found upon the

the sea-shore. The field of Orlingbury, wherein they are discovered, is very high ground, and nearly in the centre of England.

Echinus Rosaceus.

But the most scarce and curious of all the fossil echini, is a foreign one, which belongs to that sort which Woodward calls *pentaphylloides.* Some of these were sent to Dr. Woodward by Agostino Scilla, an Italian writer on extraneous fossils, who had them from Malta, and has figured them. In the year 1749 some specimens were exhibited to the Royal Society by Mr. Emanuel Da Costa: the most remarkable of which did then belong to my learned friend, E. Jacob, esq. of Feversham in Kent. One of these was sent to me from Minorca by a very ingenious gentleman, a captain of the artillery, who found it there himself. It is of a very hard stone, nearly allied to the incrustations of spar or marble, which are found in some petrifying waters: and it has taken off most exactly all the internal processes and punctures of the shell in which it was formed. When the rock was blown up at Port Mahon, several of these valuable fossils were discovered. The cast I have of this shell is so elegant, that

I have made two drawings of it. See fig. 2, 3, plate V.

I have said nothing yet of the discoid or flat echinus; of which there is great variety, from half an inch to four inches in diameter. The largest I have ever yet seen was sent to me from Minorca.

Dr. Woodward has called these, and some other sorts of echinites, by the name of *spatagi*, on what authority I have not been able to learn; except that Agostino Scilla calls them by the name of *spatago*. The Greek word for one of the species of echinus is Σπάταγγος; the ideal meaning of which does not appear from any derivation of it, and there is no word like it in Pliny.

The Pholas.

The *pholas* is a shell-fish, which extends its body forth from its shell to a great length, and bores holes in blocks of chalk and stone near the shore, as round as if they were made with a centre bit, and in these it conceals itself. It has two shells like the muscle, and a third smaller; on which account it is classed by Woodward with the multivalvular. This fish is found plentifully in the holes of the chalk which falls into the sea from the cliff over

over which the castle stands at Dover: and the fishermen extract them, by breaking the chalk with a mattock, as a bait for larger fish. The fossil pholades occur in many places: some are small; others of the same size with those on the English coast: but I have one or two specimens from Minorca, of a gigantic size.

Of Squamous or Scaly Fish.

The bodies of all fish of the squamous kinds, which were deposited in the earth, being of a tender substance and watery texture, have generally perished: but in some cases, thin scales and bones, and even the figure and bulk of their bodies, have been preserved. This hath happened to some of those few which were deposited in Sheepy Island, where the mineral copperas of the soil hath as it were embalmed them in such a manner, that while they are secured from the air, as in their situation under ground, they might last to the end of the world: and when there is much stony matter intermixt with them, as it frequently happens, the mineral is thereby so fixed that the air takes no effect upon them. The body of a fish, almost entire,

tire, was given to me from thence, which seems to have been a mullet. The scales are preserved, and have a shining brassy appearance: the cartilages about the head and gills still retain their natural polish; and many of the vertebræ, displaced by accident, are seen about the surface of the body. Many heads of scaly fish, with their jaws and teeth still entire, are found in the same repository in a petrified state, and tinged with the pyritical matter of the soil. Some of them resemble the head of the pike, and others the head of the longest river eel, or perhaps some kind of sea eel.

Squamous in Stone Quarries.

Scaly fish have also been preserved when their bodies were compressed between the flakes of slate, or stone, or coal. Some in this situation have the back-bone, ribs, head, and tail, very distinguishable, and projecting more or less from the surface, to which they adhere. Others, suffering more from the bed in which they were deposited, or some circumstances previous to their lodgement in the earth, have little more than the mere lineaments of their bones remaining, and are almost as flat as a picture. Many of these are

are brought from Isleb *, in Germany, in a kind of black fissile stone. Aldrovandus had specimens of this fossil, and has called it *lapis Islebianus ichthyomorphus.* Others still more curious have been found on the coast of the Holy Land, in the neighbourhood of Latikea, or the ancient Laodicea; of which we have the following account in Dr. Shaw's Travels †: "Upon the Castravan mountains there is "another

* In the county of Brunswick near Osteroda, in the county of Mansfield near Eistebe, and in many other parts of Germany, veins of slate are found, very near horizontal, whereon are very exact and complete representations of many sorts of fishes or plants, which appear of their natural length and breadth, but without any thickness. These lines are often described on a mixture of copper which contains silver. Some of these plants are not now known in these countries; but they may be found among the figures of Indian plants.—It appears, by several marks, that there have been great changes in nature, on the surface of the earth. Mr. Leibnitz thinks the sea once almost covered the whole, and that afterwards a great part of its waters made a passage into those hollow abysses which are within our globe. From thence proceed the shells of the mountains. But the whole of this subject deserves a more ample discussion. Memoirs of the Royal Academy, abridged by Martyn and Chambers, vol. II. p. 356, &c. When this was written, the learned in Europe were but beginning to consider the subject of extraneous fossils. Scheuchzer arose soon after, and carried on the subject.

† Folio, p. 372.

" another curious bed of whitish stone of
" the slate kind, which unfolds in every flake
" of it a great number and variety of fishes.
" These, for the most part, lie exceeding flat
" and compressed like the fossil fern plants,
" yet are, at the same time, so well preserved,
" that the smallest strokes and lineaments of
" their fins and scales, and other specifical
" distinctions, are easily distinguished. A-
" mong those that were brought to me from
" this place, I have a beautiful specimen of
" the squilla, (or prawn,) which, though the
" tenderest of the crustaceous fishes, hath
" yet not suffered the least injury from length
" of time or other accidents*."

A very fine little fish of this sort, (whereof I have a figure,) was in the possession of the late Rev. Mr. Gostling of Canterbury, and probably sold when his collection was disposed of. Another learned gentleman† shewed me a slate with the skeleton of a fish about the size of an anchovy, which a friend of his had taken

* Dr. Shaw complained that this fossil was borrowed of him by Dr. Woodward, who, (or his executors,) being repeatedly applied to by the proprietor, was never prevailed upon to return it. Q. Is it in the Collection he left to the University of Cambridge?—I see nothing of it.

† Charles Grey, esq. of Colchester.

taken from the slate of Mount Sinai, splitting it off with a pocket knife.

In Mr. Scheuchzer's collection from the quarry of Oningen, in the diocese of Constance, the petrified fish, most remarkable for its size, and the perfection of the figure, was a great pike, of which it is said that there even remained in some places the petrified flesh. This was then thought to shew the reality of the fish found in stone, more palpably than those delineations so fine and delicate, which have no substance *.

But our own country hath lately afforded what I apprehend to be the greatest curiosity of this sort that ever yet appeared. It is the entire figure of a bream, more than a foot in length, and of a proportionable depth, with the scales, fins, and gills fairly projecting from the surface, like a sculpture in relievo, and with all the lineaments, even to the most minute fibres of the tail, so complete that the like has not been seen before. It was taken from the stone-quarries of Barrow in Lincolnshire, and is now, by a fortunate circumstance, in the possession of the learned Mr. Green, Woodwardian professor of fossils

* See Memoirs of the Royal Academy abridged, vol. III. p. 83.

Jn.° Lodge Sculp.

fossils in the University of Cambridge, who has given me leave to present the reader with a figure of it. See plate VI. fig. 1.

Another very fine fossil fish of a different constitution was discovered in a block of Leicestershire coal, at the house of the late Sir J. Robinson in Northamptonshire. It is a considerable part of the body of a salmon, (or rather the image of what once was its body,) in a white sand-stone, with the lineaments of the scales: the cavity of the belly is filled with coal, which is a very singular circumstance. It was lately presented by Sir George Robinson to Sir Ashton Lever, and is now preserved in his museum.

Of Crustaceous Fossil Fish.

These, being also tender and perishable, are rarely to be met with; but the immortalizing soil of Sheepy Island hath preserved many of them. There we find not only the fragments of lobsters and crabs, but sometimes their whole bodies and claws entire. Those of the smaller kind are frequently so. Among the rest, there is the spider-crab, whose shell is studded with small tubercles, of which sort, I think, none are to be found in these

seas. A fossil crab, in very good preservation, is found in the East Indies; the legs are large in proportion to the body. The shell of the land tortoise has likewise been found in Sheepy Island, very fair and perfect; a fair specimen of which was obtained by Mr. Hamilton, who collected for sale, and was by him presented to Ingham Foster, esq. of Clement's Lane. There may be others from the same place in the collections of the curious: it never was my good fortune to meet with one.

Pediculus Marinus.

A fish nearly allied to those of the crustaceous kind (if it may not more properly be called a marine insect,) is the *pediculus marinus*, or fossil *eruca*, which has the faculty of rolling itself up like the wood-louse or hedge-hog. It is natural to suppose, that when the earth settled upon these animals, some of them would be dead, and some alive. Accordingly we find some of them extended, and others rolled up. They have been found in stone in some parts of Wales; but the most perfect are taken from a stone-pit at Dudley in Worcestershire. In the Philosophical Transactions for the year 1750, there

is

is a paper upon this rare and elegant fossil, from the Rev. C. Lyttelton, then Dean of Exeter. The fossils of this kind first discovered being of those that are rolled up, the fossilists of that time were at a loss what to call them; but afterwards, when some of them were found extended, the insect was better understood. A figure of this fossil, both rolled up and extended, was given by Mr. Lhwyd, in his Lithophylacium Britannicum, which I suppose him to have found in Wales. These figures are subjoined to an epistle written to Rivinus of Leipsic, in the year 1698. I have given a representation of this fossil in its two states. See plate VII. fig. 18, 19.

Of the Teeth and Bones of Fishes.

The teeth of fishes and other animals being formed by the Creator for weapons or tools which ought to carry a fine edge, and bear much using, are of an harder temper than any other bones. They are, therefore, more durable than brass or steel, or any instrument which art can prepare; and hence it is less to be wondered at, that the earth affords them in the highest preservation, with all the

native polish of their enamel upon them. The island of Malta has long been celebrated for the fossil teeth of sharks, which are found there in great abundance, and have gone under the name of *glossopetræ*, or petrified tongues, from a fabulous account current amongst the natives, that they are the tongues of serpents petrified. Many of them are indeed shaped much like the tongue of a bird, but none like the tongues of serpents, which are always forked, *bisulcæ*.

Many of these are undoubtedly the teeth of sharks; but there are multitudes of a different figure, and many are larger than the magnitude of the biggest shark will account for. They are of such various figures and sizes, that they must have belonged to many different sorts of fish and amphibious creatures, some of which will never come to our knowledge. Dr. Woodward refers many fossil teeth found in the quarries of Oxfordshire and Northamptonshire, to the *lupus piscis*, or sea-wolf, and many others to the shark or dog-fish. He describes, as one of the most rare and valuable fossils of his collection, a fossil jaw of the *lupus piscis*, with fourteen teeth in it, from a stone-pit at Enston in Oxfordshire. He took the pains to collect,

collect, from different parts of the world, the jaws of fish of many kinds, that he might compare and match the fossil teeth with the natural ones, thereby to demonstrate their marine origin; and this he effected in good measure with the assistance of his friend Agostino Scilla, and other foreign naturalists, who joined with him heartily in his researches*.

Fossil teeth are found in great numbers on the shores of Sheepy Island, and some of the largest and best now to be seen in cabinets were taken from thence. Those from Malta and Minorca are sometimes of the natural colour, white, like ivory, as are some of those from the chalk-pits of Kent; but the fossil teeth of Sheepy being impregnated with the copperas of the cliffs, are generally black as ink. Mr. Lhwyd, in his Lithophylacium, has figured one of these, which was four inches in length; he calls it *Glossopetra maxima cuneata Cantianorum, sive anthracina lævis, quatuor unciarum longitudine, mucrone obtuso*†.

Some

* Many fine specimens of fossil teeth and jaws are now preserved in the collection at Cambridge, with the parts of the recent animals to compare with and verify them.

† See No. 1259.

Some sea fish, instead of being armed with pointed teeth, have their palate and jaws set with enamellated bones and tubercles, for the purpose of breaking and grinding the shell-fish which they feed upon. Some of their mouths withinside are not much unlike a tessellated pavement. The *nari nari*, as it is called by the Brasilians in South America*, or, as our sailors call it, the *sheep's-head*, a large flat fish, is one of those whose palate is lined with these bony tubercles; which, when found in their petrified state in the earth, are called *bufonitæ*, or toad-stones, because they were reported by the ignorant and credulous to have been bred in the head of a toad. The enamel upon them has so fine a polish, that they have been set in rings. They are much praised as an infallible remedy (or rather a charm) against violent bleedings at the nose, and are frequently set in gold, and worn about the neck with that persuasion to this day†. Those found in England

* See Pisonis Hist. lib. v. cap. 14.

† A young gentleman of my intimate acquaintance, who was troubled with such frequent and profuse bleedings at the nose as were thought to endanger his life, and could by no means be prevented, has now for about two years past worn one

England are commonly of a dark grey or brown colour; but some foreign ones are found of an orange colour. The most elegant are rhomboidal, or square, and furrowed with ridges after the manner of a palate. Sixteen of this most valuable sort, and of various sizes, all of which probably were once set together in the palate of the same fish, were extracted from a single block of chalk, which a workman broke to pieces in the great chalk-pit at Lenham in Kent. By the favour of my friends, several of them have passed through my hands, and I have still preserved two of the most perfect; and for the singularity of their figure, and the elegance of their appearance, no fossil bodies can exceed them*. On the shores of Sheepy another sort of palates, of a tessellated construction, are found; which, like many other

one of these bufonites at his breast; and it is a certain fact, that he has seldom bled since, and never in any degree to alarm us. What share the stone may have in this, must be left to the consideration of the reader. Nothing would prevail with the gentleman to leave it off.

* Some of these I had from Abraham Tilghman, esq. of Frinstead; but the best specimen of all was communicated to me by my very respectable friend, Thomas Best, esq. of Chilson in Kent, lieutenant-governor of Dover Castle.

other fossils of that island, are perfectly black with copperas.

The vertebræ of fish being more durable than any of their bones, their teeth excepted, are found in many parts of England, but no where in such abundance as in the Island of Sheepy. They have been picked up on ploughed lands, of a great size, in our most inland counties, as well as discovered in stone-pits: in the former case, it is obvious that they must have lain near the surface. I compared one of these, picked up in Orlingbury field in Northamptonshire, some of the highest ground in England, and most remote from the sea, with the vertebræ of a salmon, and found, by the rule of proportion, that the fish to which it belonged must have been seven feet in length. I have another from Oxfordshire, which, by the same rule, gives us a fish of upwards of nineteen feet in length: and from the flatness of it, should suppose it to have belonged to a crocodile, or some vast amphibious animal of that class. These vertebræ being of a shape much more compressed and flat than those of the salmon, it is probable the length would not be so great as by the proportion above.

Dr. Stukely, in the Philosophical Transactions,

tions*, gave an account of a fossil skeleton, which he believed to be that of a crocodile, or other like marine animal, found in a stone taken from a quarry near Newark in Nottinghamshire.

Another fossil skeleton of an alligator, twelve or fourteen feet in length, was discovered in the cliff of an alum rock by the sea-shore, near Whitby in Yorkshire. The cliff is an hundred and eighty feet high, and the continual beating of the sea has broken it away, till this curious fossil lay exposed in a stratum at the foot of it. We have a description of it in the Phil. Trans. Vol. L. N° 108.

In a gravel-pit of Suffolk, abounding with fossil shells, the entire skeleton of a whale was discovered, the bones of which becoming friable and mouldering away after they had been exposed to the air, were carried off by a farmer for the manuring of his land; which purpose, pit-shells, and other extraneous bodies of marine original, are found of late years to answer better than any dung or compost: but I am informed the experiment fails if repeated a second time upon the same land, when the effect of the first manuring is worn

* Abridg. Vol. V. Part iv. p. 61.

worn out. The accident by which this art of manuring land with fossil shells was discovered, is related in the Phil. Trans. for 1744, No. 474, p. 191.

It seems, from a line of Virgil's Georgic, as if this manure, as well as that of *lime*, was then in use with the Romans:

> *Sparge fimo pingui, & multâ memor occule terrâ,*
> *Aut* lapidem bibulum, *aut* squalentes infode conchas.
>
> Georg. lib. ii. 347.

Of the Parts of Animals.

We have seen how the earth in all parts of it is stored with the remains of trees, plants, and fruits; of fish, testaceous, crustaceous, and squamous, and of other amphibious inhabitants of the waters. We are now to inquire whether the spoils of land animals are to be met with; which, though they do not occur in such plenty, nor in so many places, as the parts of fishes, are yet found under such circumstances, and in such forms, as render them worthy of observation.

If we compare the inhabitants of the land with those of the waters, we cannot but allow that the waters in any given space are abundantly more stocked with living crea-

tures

tures than any equal portion of the earth's surface; and if it is also considered that the waters of the sea occupy more than twice as much of the terraqueous globe as the land, the proportion of sea animals must vastly exceed the others. Add to this, that the classes of corallines, lithophyta, and many of the testaceous kinds, are of a substance as hard as stone, and of a much more durable texture; whence it is not to be wondered at, that they abound so much more in the earth as petrifactions: we are to recollect likewise, that the catastrophe of a deluge would soon corrupt, destroy, and disperse the parts of such living creatures as die in the waters, while the natives of the sea would struggle with the difficulties of an inundation, and be at last deposited alive in the earth, when the settlement of the strata took place, and the waters retreated; as it is evident many of them actually were, from the postures and circumstances in which they are now discovered.

All these things being laid together, the earth, as a repository of extraneous fossils, ought to exhibit the remains of fishes in much greater abundance and in better preservation than of such creatures as inhabited the land.

So far as petrified bodies are monuments of a flood, the productions of the sea are most proper for that purpose: if the productions of the land were discovered in the land, we might possibly infer from their situation that some extraordinary revolution had happened to the earth, but we should not have been able to shew that it happened by means of water, and from an alteration in the sea. As things are now, the case is clear; the spoils both of the sea and land all concur in the same testimony. These latter, though by no means so common as the other, for the reasons above mentioned, are yet common enough to shew, that land animals of all kinds were destroyed upon that occasion, when the earth was stored with the spoils of the ocean.

Sir Hans Sloane's Observations on Fossil Bones.

That eminent naturalist Sir Hans Sloane, the father of the British Museum, hath made some observations on the fossil bones of elephants and other land animals, which being very learned and pertinent, I shall here give the substance of them in as few words as I can.

Amongst the other remains of land animals,

mals, the horns and bones of a very large sort of deer, which he supposes to have been the moose deer of America, the largest quadruped of that kind in the known world, have been discovered in the morasses of Ireland. A buck or stag of the moose deer kind has been taken by the American hunters in New England, which measured at the withers fourteen spans in height, that is, above ten English feet. The horns were between four and five feet long from the head to the tip, and broad in proportion. A pair of the fossil horns of this animal, of a monstrous size, are preserved in the British Museum.

As to elephants, they have two kinds of teeth; the *dentes exerti*, or tusks; and the *molares*, or grinders. Fragments of an elephant's tusk were dug up in a gravel-pit at the end of Gray's-Inn-Lane, at the depth of twelve feet. They were much decayed and brittle, and astringent upon the tongue like calcined substances. The learned author imputes this to the effect of subterraneous steams, which probably have their share in changing the quality and texture of bodies that have rested long in the earth. I have myself observed this remarkable stypticity in

in petrified bones which I have taken out of some stone-pits in Northamptonshire, equal, if not superior, to that of a tobacco-pipe of burnt clay; and I suppose it is a quality common to most petrified bones.

Another considerable portion of an elephant's tusk was sent to Sir Hans Sloane, by Mr. Morton, author of the Natural History of Northamptonshire; in which, as in the last, the tusks which we call ivory appear to be formed of coats one over another, like those which appear when a tree or an onion are cut transversely. He mentions another tusk which came from Siberia; where they are so common, and so little decayed, that they are used all over Russia for ivory. They are mostly to be met with in the coldest parts of Siberia. The vulgar people in Russia have many fabulous reports among them concerning these teeth, as if they belonged to a creature inhabiting the subterraneous regions; but the more learned and sensible affirm them to be elephant's teeth, brought thither at the time of the deluge.

Fabulous accounts of Giants' Bones.

In England many grinders and bones of elephants have been dug up in various parts:

one grinder, sent by the Rev. Mr. Morton of Northamptonshire, was taken up with the skull of an elephant near Gloucester. In time past it was not uncommon for these grinders and bones of elephants to be shewn about as the bones and teeth of giants, and to be boasted of as undeniable monuments of the existence of giants; which, upon a more accurate examination, proved to be the bones and teeth of elephants or whales. And to the same original we must refer the gigantic skeletons mentioned in history by Philostratus, Pliny, and Strabo, of forty, fifty, and sixty cubits high. An ancient historian also tells us, that in England, in the twelfth century, the earth being torn away by the overflowing of a river, a gigantic skeleton was exposed to view, of fifty feet in length. Many fossil bones and grinders, valued for ages together, in different parts of Christendom, as the relics of gigantic human bodies, have been compared with the skeleton of a real elephant, and found to correspond so exactly with it, as to leave no room to doubt that they belonged originally to that animal. The most curious and complete skeleton of an elephant was discovered

in Thuringen, 1695; the head was entire, and had four grinders with the two tusks, several of the vertebræ of the neck and bones of the body; all of which were found together twenty-five feet under the surface of the earth, with seven strata regularly disposed above them.

After several accounts to the same effect, he mentions the opinion of some learned men, endeavouring to account for these things, that elephants were brought into Europe by the Romans, and buried. But to this, as he has observed, there are two insuperable objections. First, that elephants of such a magnitude never could be brought alive into the latitudes where they are found, even in the cold regions of Siberia, where the severity of the climate would not permit an elephant to live three days. Secondly, that no art of man could place these skeletons in the situation where they are found, under strata of the earth, some of solid stone, and all so regularly disposed, that it is certain they had never been broken into and disturbed since their settlement. Besides, the Romans, who set so high a value upon ivory, would never be so absurd as to bury it wantonly in the

the ground*. The conclusion therefore is necessary, that they were brought and deposited by no other cause we can assign but that of an universal deluge. There are many other learned observations on this subject by the same eminent naturalist, all tending to establish the same conclusion: but what I have extracted seems to be more than sufficient for this purpose.

I once saw a large bone in the possession of Mr. Joshua Platt of Oxford, found in a stone-pit at Whitney, or Burford, in that county, which appeared to be the thigh-bone of an elephant: but the following curious circumstance was very observable, that the head of this bone was rubbed away and ground flat on one side; whence he supposed very rationally that it had suffered some extraordinary attrition, either with being agitated itself, or lying in the way of some

 other

* The learned writer might have given it as another argument against the notion of their having been buried by the Romans, that bones and teeth are found by themselves detached from the rest of the skeleton; which shews that they had suffered some violence before their interment; whereas if they had been buried where they died, the bones of the entire skeleton must have been found near to one another.

other hard bodies driven against it by a current of water*.

Torquoise Stone.

The *torquoise* stone, which is reckoned among the gems, and is so called because it is chiefly brought from Turkey and Persia, is fossil ivory, tinged with particles of copper; and is either green or blue, according as the copper happened to meet with an acid solvent or a volatile alkali. Theophrastus, in his History of Stones, speaks of Ελεφας ορυκτος, which Pliny from him calls *ebur fossile*, and describes it as coloured with black and white. The late Sir John Hill, in his notes on Theophrastus, endeavours to shew, that the word μελαινι in the Greek should be translated *blue*, but on what Greek authority does not appear. Sometimes the torquoise has a fine pale blue equably diffused through it when taken from the earth; but is more frequently found irregularly spotted with the metallic matter; which the artists, by the application of a proper heat, spread equably through the body of the stone. The learned Dr. Mortimer was of opinion, that some specimens

* Mr. Platt has given an account of this himself, in the Philosophical Transactions, Vol. L. part II. No. 68.

cimens of the torquoise from the East are not fossil ivory, but mineral exsudations from a black stone. He allows that those brought from France and Spain are fossil ivory, coloured with copper. It is easy to counterfeit this precious stone, by tinging ivory with a solution of copper: but I should apprehend, a judicious lapidary might detect the fraud; because the factitious torquoise will neither be so hard nor so heavy as it ought to be, and therefore can scarcely be made to take so high a polish *.

The bones of elephants have been digged up in great abundance on the banks of the river Ohio in North America, which are at least seven hundred miles from the nearest sea coast. It was computed, from the quantity, that there could not be less than thirty of their skeletons. Some tusks were taken thence more than seven feet in length, and with them were found, not the common grinders of elephants, but large teeth with fangs belonging to some other vast animal. This is a confirmation of what I mentioned

o 4 above,

* There is a curious discourse on the mines of torquoise stones of France, in the Memoirs of the Royal Academy, in which their nature as fossil bones is very clearly ascertained. See Martyn's Abr. Vol. V. p. 91, &c.

above, that these were not the skeletons of buried elephants, but bones which by some violence had been disjoined and separated from their natural companions before their interment. No elephants have ever been seen in America since the first discovery of it by Europeans: nor indeed could they have lived in the climate here spoken of, on account of the severe cold of the winter. The same tusks and bones have been found in Peru *.

When these accounts are compared, they will shew how impossible it is to account for the discovery of the remains of these animals, as some have attempted, by a supposed alteration in the axis of the earth, whereby the latitudes on the earth's surface, and consequently the climates, were changed. The elephant is an inhabitant of the torrid zone: but if we change the axis of the earth so as to bring these parts of the Ohio near to the equator, we shall shift the country of Peru to the regions within the antarctic circle; so that we shall lose as much as we get. This solution, therefore, (even allowing that there were no other difficulty in the way,) is too partial to account for the phænomenon; which

* See Phil. Trans. Vol. LVII. N° 45. p. 2.

which demands some general cause, some accident or other, which extended alike to all regions and all climates of the earth. Siberia, Britain, North America, and South America, have their fossil elephants, and have consequently all been subjected to some general catastrophe, for which no partial hypothesis can account.

It is here to be remarked, that the bones of land animals (I mean the *diluvian* bones) are often found in the earth unpetrified. Being lodged at considerable depths under ground, and secured from all the impressions of the atmosphere, they are in as good condition, or better than many bones which have lain near the earth's surface for but a few years. A learned friend of mine, who has been indefatigable in these matters, and to whom we are indebted for an excellent Treatise on the Deluge, which enters more particularly into the subject than any published before it, extracted many different kinds of bones from a wonderful pit, in a place called Hutton-Hill in Somersetshire. Six grinders of elephants, one of them lying in the jaw, two thigh-bones, and part of the head of an elephant; part of a large deer's horn, and the core of another horn of some animal

animal of an extraordinary size; the entire head, with the teeth, of an hippopotamus, or river-horse; almost the entire skeleton of an animal about the size of a fox, but whose teeth, jaw, and bones could not be reconciled with any known European animal. All these bones, and many more of different sorts, left behind in the pit, till the earth above fell in upon the cavity, were found at the depth of seventy feet below the surface. These bones and teeth were extremely well preserved, and retained their native whiteness; as appears from some specimens of them in my own collection, communicated to me by the above-mentioned gentleman.

At the stone-quarries of Weldon in Northamptonshire, at a considerable depth in the earth, and immediately under a vast solid stratum of stone as hard as marble, were discovered, some few years ago, the bones of a lion, and some teeth, which are supposed to be those of a rhinoceros. Some of these I obtained by the favour of a friend*, which are as fresh in all appearance, and, with their enamel of its natural colour, nearly as perfect

* My dear and worthy brother, the Rev. Mr. Bridges, rector of Orlingbury, who for several years past has been my fellow-labourer in the study of fossils, &c.

fect as if they had been taken from the head of a living animal.

Petrified Human Skeletons.

But the most extraordinary of all, and with which I shall conclude this chapter, are the remains of petrified human skeletons. I have by me two fossil teeth, which appear to be human. The core or bony part of them is decayed like rotten wood, and nearly perished; but the coat of enamel is perfectly preserved, and tinged of a pale green, like that of the torquoise stone or fossil ivory above mentioned. These teeth having been taken from the collection of an ingenious mechanic in Northamptonshire, who was not alive when they came to my hands, and had left no account of them in writing, I was never able to learn where they were found: but most of the articles in his possession having been collected from the large gravel-pits at Desborough, on the borders of Leicestershire, I think it most probable that they came from that place. In the cabinet of the French king at Paris, I saw the hand of a woman petrified, and of the same colour with these teeth. It is reported to have been dug up in a church-yard; but the history

history of it did not seem to be well ascertained*. I have often thought of this phænomenon since, and think it had all the appearance of a limb first struck with lightning, and shrivelled into a callus, and after that petrified in a kind of soil where it was tinged with metallic vapours, till it acquired the complexion of the torquoise, plenty of which have been dug up in several parts of France.

It was an observation of Scheuchzer, that while we discover the diluvian relics of other land animals in great abundance, very few are to be met with of the human species. Therefore he speaks of it as a most remarkable thing, that the parts of two fossil human skeletons were found in a slate-pit at Oningen; several vertebræ and bones of the skulls; some decayed like bones in common earth, and others incrusted with stony matter.

But petrified human bones, howsoever scarce they may be in England and Germany, are to be met with in the countries on the northern coasts of the Mediterranean sea. An ingenious and philosophical gentleman,

* See a farther account of fossils in France, in my Observations in a Journey to Paris, Vol. II.

tleman, a captain in the artillery, when stationed in Minorca, told me in a letter from thence, "I have seen a stone full of fossil "bones which came from Gibraltar—there "was a complete human skull found in the "same rock, which is in the possession of a "gentleman at Gibraltar." My ingenious correspondent gave me reason to hope that he might some time be able to place it in my collection. A petrified human skull is preserved in the library of Sidney College in Cambridge, which I presume (for I have not yet seen it) is no accidental incrustation, but a true diluvian petrifaction, like that from the rock at Gibraltar*. This rock, in which the fossil bones are found, consists of a very hard stone, of a reddish colour like brick. The same sort of rock is found on other coasts, and is stored in like manner with fossil bones of land animals. I had the following account of it from a learned nobleman, who spent much of his time in that quarter of the world, and was particularly inquisitive as to all the branches of natural history and natural philosophy. He informed me, that the

* This skull was brought from the island of Candia or Crete; it is only a fragment, including the sockets of the eye, the nose, the upper jaw and teeth.

the island of *Ossoro* (or as some call it *Ossera*) in the Gulf of Venice, and which was probably so named from the *bones* found there, has this same kind of red rock which is found at Gibraltar, and that it abounds with fossil bones, most of them supposed to be human, because so many portions of ribs and skulls which appear certainly are so. He was so good as to favour me with a block of this stone, which is full of these uncommon bones. It suffered in the carriage, so that some of the bones are a little rubbed and defaced. The like rock is found again on the coast of Dalmatia, and may in the whole be traced for near two hundred miles in length, and to a vast breadth and depth: but what is most wonderful, and would be incredible if it were not attested by eye witnesses, wherever it is searched, whether above or below, to any depth below the horizon, it still presents to us these fossil human bones; as if the place had been set apart for the charnel-house of the former world, and these bones had been purposely collected together in infinite multitudes at the flood, to be locked up in this indissoluble rock, where neither time nor any other accident can destroy them. And there they are likely to rest, with that rock

for

for their sepulchre and their monument, till the conflagration.

General Observations and Directions on the Subject of Fossils.

To the foregoing description of fossils, some general observations may be added, to give a farther understanding of the subject, and lead us to the most authentic and philosophical theory of the terraqueous globe.

First, it appears that there is a constant circulation of water or moisture through all the cracks and even the most solid matter of the earth, as really as there is a circulation of blood and juices through the most minute vessels of the human body, and even through the substance of the bones. The huge strata of rocks and marble, which strengthen and support the body of the earth, are analogous to the bones of the human body, and may properly be understood as the bones of the terraqueous system. The hardest stone, when first taken from its subterraneous bed, is always found moist to the very heart of it; and is therefore penetrated by water, which is silently and constantly making its way through it: and this water is derived either from

from the humidity which distils from above, or to the more active steams and vapours which are always ascending from the lower parts. To this constant passage of water, carrying with it metallic, mineral, and stony particles, we owe many of those veins of metal which are found in the fissures and crevices of the earth, where the water hath conveyed and left them.

In subterraneous caverns, sparry and crystalline incrustations are formed; which when they lie on the bottom, are in tubercles and masses of irregular figures; but are pointed like icicles when they are found depending from the roof; great variety of which, and of strange forms, are to be seen in the caverns of the Peak of Derbyshire, particularly in Poole's Hole, as it is called, near Buxton.

To this also many unexpected phænomena are to be imputed which we discover in those extraneous bodies which are confined within stones and other solid matter of the earth. Sometimes it has happened, that when a shell filled with stony matter has been buried in a stony stratum, the testaceous substance of the shell has been dissolved and conveyed away through the joints and pores of the stone,

stone, while sparry particles have been introduced by the water in their stead: and thus it has come to pass, that a stony nucleus has been found with a covering of spar or crystal of the same form and thickness with the shell in which it was moulded. In other cases, when an empty shell has been thus inclosed in a bed of stone containing spar, the same cause that has filled it with spar, has afterwards carried away the shell; so that the figured casts of spar have been found loose in the cavity of the stone; and sometimes several have been found together in the same cavity. To the same cause it may be owing, in some instances, that we find inclosed fossils either filled or petrified with particles of matter different from that which incloses them: though, indeed, it must be confessed, the more general cause of this effect was the transportation of bodies at the flood from one sort of matter to another.

A Dissolution of Stony Matter happened at the Deluge.

The second thing observable from the situation in which fossil shells are found, is the dissolution of stony matter at the deluge; because shells and other extraneous bodies,

some of them very thin and tender, are every where found in the midst of stone and marble, and even flint itself. It is not the question, whether we can assign an adequate cause for this effect: the fact itself is indisputable. How could stone and flint fill up the cavity of a shell, so as to take the impression of its finest lineaments, and all this perhaps through a perforation into which a pin could scarcely be introduced? How could this possibly be, unless that matter had not only been dissolved, but even reduced to its finest particles or first principles, as a metal or mineral when in a state of dissolution over the fire? The same matter which filled them within, has also covered them without, and is applied to them in such a manner, on all sides, as could not have happened unless it had been as flexible and soft as a mixture of lime and water. Many fossil bodies, and those very tender, are as closely covered with flint as if they were enwrapped in a mass of the finest paste or mortar.

Dr. Woodward, being convinced by what he saw, embraced this opinion of the dissolution of earth and stone at the deluge; but was very much misrepresented and opposed in it by many learned and ingenious men of

his time, as if the doctrine were too extraordinary to be easily digested. Mr. Pope, who was neither philosopher nor naturalist, made himself merry with supposing a menstruum for dissolving the stone in the bladder, composed of Dr. Woodward's *deluge-water*. But it can never be absurd to believe a fact attested by palpable evidence, however unaccountable it may seem in itself: our senses in such a case must be permitted to have the controuling of our understandings. We are reduced to this alternative: either the shells we find in stone are not real shells; or the stone which contains them was dissolved before it received them. But we can demonstrate them to be as real as the shells which are now taken from the sea shore; therefore the consequence is unavoidable.

This illustrated by a parallel Case.

There is a difficulty here which we must stop a while to consider. It was urged against Woodward, as an impossibility in nature, that marble should be dissolved, while shells and bones, yea even fruits and vegetables, were preserved entire. But this can be no impossibility; forasmuch as nature presents us very commonly with a parallel fact. Ice is a body

as hard as stone, and may be formed into optic glasses. Now it comes to pass very frequently, that ice incloses dead grass, and sticks, and leaves of trees, which are locked up as fast within it as sea-shells in stone: but when the air changes, the solid ice loses its cohesion, and falls away into a fluid; while the tenderest leaf it inclosed remains just as it was before. What is the reason of this? The answer is plain: the leaf is of a texture different from the ice; it is formed of fibres complicated together; while the ice consists of simple particles, which adhere only by juxta-position, and are ready to fall asunder as soon as the cause is withdrawn (that is, the cold air,) which kept them together. Add to this, that the materials of a leaf are essentially different from the matter which forms ice. The case is parallel with respect to stone: it is formed of independent granules, which must fall asunder when the cause of their cohesion is affected. But the same consequence will not hold against a body composed of a complication of fibres, which will still hang together as before: and this seems to be the true reason of the difference.

Shells

Shells more durable than Marble.

It is observed, that, in old Roman and Etruscan ruins, containing fossil shells in the stone of their walls, and which have been standing for above two thousand years, the wind and rain which has in such a tract of time gulled and worn away the surface of the stone, has made little or no impression upon the shells, which are unhurt and prominent above the surface. There is an essential difference in the structure of these two bodeis, on account of which the one is destroyed and the other preserved.

How many causes, or what suspension of causes, might contribute to the effecting of a dissolution, it may be worth our while to consider; and though we can never have an adequate conception of the case, we may find some satisfaction concerning this marvellous effect, to which we owe the preservation of so many curious and valuable remains of the antediluvian world.

In the first place, then, we are to take into this account the powerful effects of steams and vapours of water, which will slowly dissolve the hardest substances, if fire co-operates with them in a proper degree. Attrition

tion also, be it that of water against a solid body, or of one solid body against another, will have much more effect upon stone, than upon shells which can better endure the force of it, or upon soft and flexible bodies which yield to it *, Dr. Woodward was of opinion that the cause of gravity was suspended during the progress of the universal deluge; and it probably was to a certain degree, because we do not find that specific gravity had any share in the precipitation of the solid materials which composed the strata of the earth; the lighter strata being found promiscuously under the heavier; chalk being as commonly under flint, as flint is under chalk; and heavy nodules of the pyrites being placed among the lightest kind of earth. If the effect of gravity was taken off in part, that of cohesion

* I have sometimes thought, that attrition alone, such as must have happened from the disorderly and violent motions occasioned by the flux of waters at the deluge, might be sufficient to produce such a quantity of what we may call *powder of stone*, as would furnish matter enough for the formation of all those strata of stone which lie within our observation. Such is the magnitude of the earth's body, that it is absolutely nothing more than the superficial skin of it which we are able to dig through. We are very apt to consider that depth as great in itself, which has no greatness but what is relative.

sion might be so likewise; they being both supposed to proceed from the same cause: and thus the solution of solid substances might partly be accounted for. But there is one positive cause, never taken into this account, which ought not to be omitted: for we are to account for the phænomena of the deluge from a natural agency of the elements so far as we are able, and not have recourse to miracles till nature will carry us no farther. It is then by no means improbable, that the agent which we call lightning, and which acts so manifestly in electric experiments, must have had its share in the dissolution and dissipation of the solid parts of the earth. The sky, from those black and dense clouds which enveloped the face of the deep, and poured down torrents from the heaven, would send forth such thunder and lightning as an inhabited world never yet saw or could endure; the shocks of which might produce many of those strange separations and subsequent associations, of which we see the effects at this day, when we penetrate into the bowels of the earth.

But whatever the concurring causes might be, the fact of a dissolution is certain: and Dr. Woodward has endeavoured to shew that

such a thing was to be expected, according to the terms of the Mosaic account of the flood in the Scripture *. It was denounced, that *the earth*, as well as *man*, should be *destroyed;* and the word, by which this destruction is expressed, signifies *to corrupt* and *dissolve*, as bodies are destroyed in the grave. The Septuagint translators use the words Καταφθειραι πασαν την γην, which express the same idea of corruption with the original; and even the Vulgate Latin adopts the phrase of *dissipans terram:* from all of which, the destruction was understood to be of such a kind as should reduce the earth to its first principles. And the learned author above mentioned insists, moreover, that nothing less could have answered the design of Providence in this affair; it being necessary, as he contends, in order to lessen the temptations of mankind, as well as to punish them for their abuse of the world, to recompose an inferior and a poorer earth out of the materials thus dissolved, that is, out of the ruins of the former; which could not be brought to pass without a thorough decomposition.

I fear it was one reason why Woodward was

* See Nat. Hist. of the Earth, p. 88, edit. 2.

was much more opposed and contradicted, and even ridiculed in his opinions by some learned men, because he had such frequent recourse to the Sacred Writings; which topic of reasoning, however just and proper it might be in his case, and upon his subject, will never become popular. This, however, was no disrecommendation of himself or his learning with Sir Isaac Newton, and surely it ought not to have been so with any of his followers.

Highest Parts of the World have been covered with Water.

Thirdly, it appears from such extraneous fossils as came from the sea, even from the deepest parts of the sea, and which are discovered in the highest mountains of the world, that the sea has been disturbed from its bottom, and that the highest parts of the world have been covered with water. Scheuchzer's diluvian trunk of a tree on the top of Mount Stella, above two English miles in perpendicular height, is a proof that the earth has been so far overflowed. There may be evidence in the Andes of America, those mountains which tower into the air so much higher than the Alps, that it was co-

vered

vered to a greater height. And for this we need not have recourse to extraneous fossils.

Disposition of the Earth into Strata demonstrates a prior Dissolution.

Wherever the matter of the earth lies in flakes or strata, horizontally disposed one below another, such matter has subsided out of water: at least it may be said, that we know of no other means by which such a disposition of the matter of the earth could be effected in a natural way. This might be carried still farther: for we know of no perfect cohesion but in consequence of a prior solution. Lime cannot fix into mortar till it has first been dissolved in water. Metals rarely have their true solidity till their ore has been fused in the fire. The hardest incrustations of spar and marble are composed of atoms precipitated from the water in which they were suspended. This principle seems to be so general, that the solidity of a rock of stone may be taken as a proof that water has once been higher than that is. But, not to insist upon this, let us take the top of Mount Stella as the high-water mark. How could the earth be overflowed to that altitude? Must not the waters come either from

from above or below? The atmosphere, supposing its weight to be wholly owing to the vapour of water suspended in it, can contain but thirty-three feet of it; so that all the moisture of the atmosphere condensed into water and falling in rain, could overflow the earth to a depth no greater than that of thirty-three feet. If the ocean be allowed to occupy two-thirds of the earth's globe, and to be a mile in depth, one part with another, what will this do? If it were all to be converted into vapour, and to fall in rain, it could only flow back again into its own channel. Where then shall we find a quantity of water to drown the earth to the height of two miles above its present horizon?

To answer this difficulty, and reconcile theory with appearances, some have conjectured that the axis of the earth was changed; of which we made mention above. Others have thought that the centre of gravity in the earth's globe was altered; in consequence of which, the water, being specifically lighter than earth, would change its place, so that what was sea would become dry land. Others have supposed, that the diurnal rotation of the earth was suddenly stopped; in which case, the water, still retaining its acquired

velocity

velocity would keep running on and overflow the land.

As these are all miracles, and it is allowed that the facts which appear to have happened, never could happen without the assistance of a supernatural power; the thing may be done at a cheaper rate, and in a more effectual manner, by taking the old miracle of the sacred account, than by taking these new ones, which have nothing but conjecture to rest upon, and will not agree with the phænomena when we have got them. According to the sacred theory, all is easy and consistent. It describes the earth as a concave sphere of solid matter, founded upon the floods: by which it is meant, that it contains underneath its foundations a vast abyss of water, which retired to the internal parts at the creation of the world, and was brought forth once more to the surface, when *the fountains of the great deep were broken up.* I know of no philosophical argument against such a structure of the earth that seems to be of any weight: and if the earth is 8000 miles in diameter, as is demonstrable from the astronomical mensuration of a degree upon its surface, there can be no difficulty in finding room enough for a reservoir of water sufficient

sufficient to drown the world to any height required. This account of things seems as reasonable as it is authentic; it agrees best with observation, and gives an easy and natural solution of every difficulty.

In justice to the sacred theory, it should always be remembered, that the same book which reveals the universality of the deluge, discovers to us likewise a reservoir of water sufficient to account for it. Take these together, (as every system is to be compared with itself,) and all difficulties vanish. If we choose to have this mode of drowning the world described in the language of a poet, Ovid will give it us: his words are as full to the purpose as those of the Scripture itself, from whence they were undoubtedly borrowed.

> *Convocat hic amnes, qui postquam tecta tyranni*
> *Intravere sui, non est hortamine longo*
> *Nunc, ait, utendum: vires effundite vestras.*
> *Sic opus est:* aperite domos, *ac,* mole remotâ,
> *Fluminibus vestris totas immittite habenas.*
> *Imperat. hi redeunt, ac* fontibus ora relaxant.
> *Ipse tridente suo* terram *percussit: at illa*
> *Intremuit, motuque* sinus patefecit aquarum.
>
> Met. lib. i. 276, &c.

I cannot but wonder that any philosophical writer should hastily pronounce the notion of

of an abyss of waters under the earth (as some have done) *an egregious absurdity.* I cannot see this absurdity in the doctrine: it is so conformable to what we see of nature, that I flatter myself I should have embraced it as the best and only sufficient hypothesis that ever was invented, even though it had not been found in the Bible. The heathens took by tradition this method of drowning the world by waters from underneath, though it contradicted their own philosophy, who maintained that the heavier matter was always below the lighter; but the earth's globe, as we find by experiment, was not constructed on that principle: for the lightest matter is commonly found in a situation below the heaviest; and therefore water may be underneath the earth.

Present Disposition of the Earth a Work of Providence.

I would observe, fourthly, that the wisdom of Providence is no-where more discernible than in the present disposition of fossil bodies under the earth. We see the traces of a conducting power, which has acted for our instruction as well as our advantage; an object undoubtedly worthy the attention of Providence.

dence. What else could have deposited coal for fuel in those barren regions where no trees are to be found, as in the most mountainous parts of the Peak of Derbyshire, &c.? What else could have lodged the treasures of the mine at so just a depth, as to exercise the labour of man, without placing them out of his reach? Insomuch that it is probable the earth may have few or no treasures worth finding, below that depth to which art and labour can penetrate. What else could have brought together the different productions of the globe within that small tract of land in Sheepy Island; a spot where the soil is as much accommodated by its nature to preserve the tenderest substances, as the aromatic oils and spices of Egypt to preserve a human mummy? There the fruits of the East and West Indies; bones, teeth and shells from the fish of all climates; the elephant of Africa, the tortoise of America, are met together as if they had been purposely sought for, and carefully laid up, for a testimony of some great transaction, in which all ages are interested? What, again, but the interposing hand of Providence, could have set apart those durable rocks on the Mediterranean coast as the grand repository of

of animal bones; which, if they had been left to their chance, might have been dispersed to all quarters, and have perished long ago in the earth? In short, so manifold, so wonderful, and so entertaining are the evidences of an universal flood, that the belief of it is no virtue: it is in a manner extorted from every inspector of the earth and its contents. It seems, therefore, very extraordinary and unaccountable, that the late ingenious Swede, Linnæus, whose name is now so eminent in natural history, should declare himself unable to find any *remains* of an *Adamitic earth.* For my part I can see little else: I see shells, bones, trees, fruits; which never could be the shells, the bones, the trees, the fruits of the earth we live upon*: therefore they must have belonged to a former earth; and as we know that such a former earth did exist, and has been destroyed, it is not wonderful that we find the remains of it—it would rather be wonderful if we did not. If it were known that a spot of ground had formerly been a church-yard, no person could be surprised that human bones should be discovered there; nor would he ever

* Because they are found in climates to which they could never belong naturally.

ever be tempted to account for them as the natural or accidental productions of the soil. And what is this whole earth we now live upon, but the burying-place of the last? What are the fragments and relics of the earth and sea, which we have been reviewing in such abundance, but the evidences and monuments of such a former world, and of the flood which destroyed it.

Directions to Fossilists.

To these observations, it may be proper to add some brief directions to those who may be desirous of searching for the different kinds of fossils, particularly the extraneous. All the pits that are opened in the earth for the taking forth of what we call the native fossils, as clay, or gravel, or chalk, or stone, or slate, or coal, or lead, or iron, &c. are worth examining, and will frequently afford many curious articles. But the most convenient places for this purpose, and which are often the richest, are the earthy cliffs which hang over the sea, and break away occasionally as they grow loose with the beating of the weather, and are undermined by the waves. The extraneous fossils which they contain are thus brought forth to light,

and when they fall upon the beach, and the sea has washed away the earthy parts, they are exposed to view. The first spot of this kind in the kingdom is Sheepy Island, so frequently mentioned already, whose northern cliffs keep mouldering away with time and weather, so that half an acre, or more, has been known to fall down at once; after which, the contents of the earth are exposed to the washing of the sea, and are picked up by the gatherers of copperas*.

The cliffs and shores by the sides of the Severn, especially near Pyrton passage, in Gloucestershire, have afforded many choice specimens; and all other cliffs and precipices, especially those that are exposed to the beating of the sea, are worth examining. Most

* Once upon occasion when I went to search these cliffs with a friend or two, and some people of the place, we had walked under the cliffs a considerable way, and were obliged to keep very close to the foot of them, it being then high water, or near it. Soon after we had ascended at the end of this narrow path, we heard a noise like that of an earthquake, or the report of cannon at a distance, which we soon understood to have proceeded from the sudden fall of at least a thousand loads of earth, which buried the path over which we had walked. As it was then just at the point of falling when we passed by, we had reason to be thankful that the shock of our feet did not set it a-going.

Most of the chalk-pits of the chalk-hill of Kent, from Dartford and Maram's Court Hill near Sevenoaks, to the white cliffs of Dover and Folkstone, are rich in extraneous fossils. One of the capital fossils of my own little collection came from the chalk-pit at Lenham. Great part of Mr. Lhwyd's collection, now in the Ashmolean Museum at Oxford, came from the stone-pits of Oxfordshire, especially from those of Stunsfield and Shotover. The black fissile slate which is found over veins of coal, and the brown nodules that occur in iron mines, which they call cat-heads, afford variety of fossil plants; vast numbers of which have been discovered in the coal mines of Somersetshire, Gloucestershire, Shropshire, and Glamorganshire. Many curious things have been found in the stone-pits of Northamptonshire, of which a very good account is given by Mr. Morton, in his Natural History of that county. Amongst the stone of that rock which skirts the Weald of Kent, I have found the cornu ammonis, from one inch to 18 in diameter, some of them squeezed almost flat; the mailed and paper nautilus, almost as large as the nautilus Græcorum; the trochus, four inches in diameter at the base; oysters of different

 sizes

sizes in the highest preservation, and amongst them the tree oyster; the pinna marina; the muscle; wood petrified and perforated by sea-worms, as the piped waxen vein of Sheepy; the bucardites; the arca Noæ; the anomia lævis margine sinuato, anomia striata, pectines and pectunculi of various sizes, echinites spatagus, cordatus, pileatus, and fibularis, the cochlitæ in vast masses, and well preserved; with many others, of which I cannot here give a particular description: so fruitful may a single spot be found by one who examines it attentively for a long time, as my situation formerly in that part of Kent gave me an opportunity of doing.

The Lithophylacium of Mr. Lhwyd, reprinted within these few years at Oxford, and Dr. Woodward's Catalogues, now become exceedingly scarce, will give information to those who desire a more accurate acquaintance with the English fossils; and to these I must refer for farther satisfaction.

An Explanation of the Figures of Plate VII.

This Discourse on Fossils may fall into the hands of some readers, who are absolute strangers

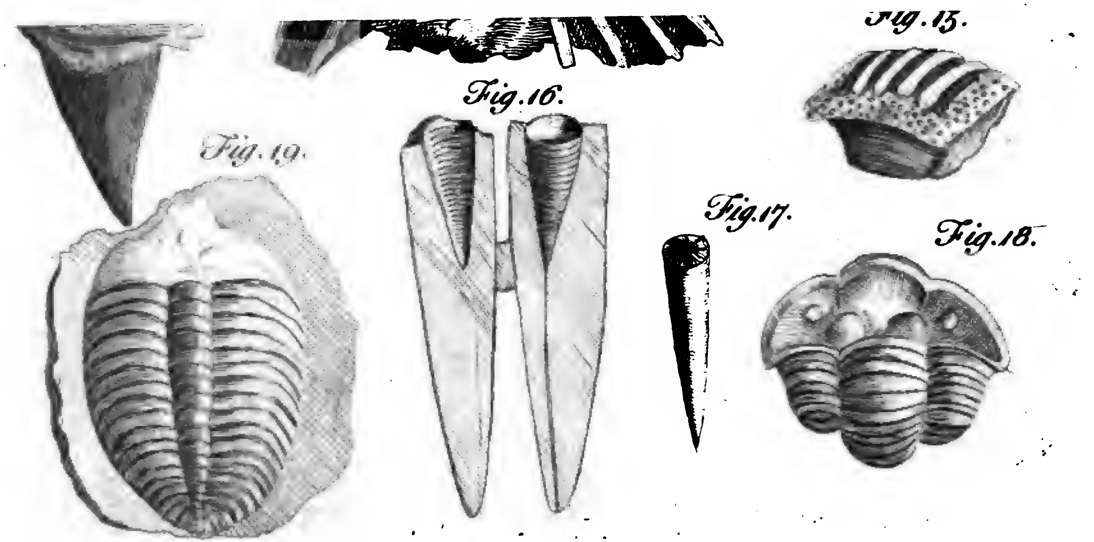


Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.

Fig. 19.

strangers to the kinds of bodies therein treated of; therefore I thought it necessary to add a few figures, each of them representing some one specimen of the several classes of figured fossils, nearly in the order in which they are laid down by Mr. Lhwyd in his Lithophylacium Britannicum; to which book, as the most convenient upon the subject, I must refer those who desire to see a greater variety of figures, with their explanations.

Fig. 1. *Iceland crystal.* A transparent body of a rhomboidal form; some specimens of which (but of an inferior sort) are found in England. This crystal has the peculiar property of producing a double refraction in the visual rays that pass through it, so that a single line drawn upon paper appears like two parallel lines.

Fig. 2. *Selenites rhomboidalis.* This is another transparent body, generally found in clay, and consisting of thin parallel plates, into which it is easily split. Sometimes it has ten sides, sometimes fourteen. It is nearly allied to *talc*, and to a glittering substance found in stone and sand, called *mica.*

Fig. 3. *Fluor,* or *spar;* commonly found in the joints and fissures of stone; much like some crystals in its form, and scarcely to be

distinguished from them without putting it to the test of an acid menstruum.

Fig. 4. The *astroites*, or *fossil coralline*.

Fig. 5. A *lithophyton*, or *fossil plant*, found in nodules of stone, which, when split, exhibit the lineaments of various plants, the greater part of which belong to the kinds of fern. The print is often concave on one half of the stone, and convex on the other.

Fig. 6. The fossil *ammonite*, or *cornu ammonis*, a shell of which numberless varieties are found in the earth, though but one species, and that very small, has yet been found in the waters.

Fig. 7. The fossil *nautilus*. The specimen here represented is the central part of a large *nautilus Græcorum*, such as are found in the vast nodules of the *ludus helmontii* from the cliffs of Sheepy Island. These shells, with all those of the snail kinds, are called *univalvular*, as consisting only of one entire shell.

Fig. 8. A *bivalvular* shell, of those which are called *anomiæ, irregular*, because the two valves are not equally matched; the beak of one valve projecting forward, and covering the beak of the other. This specimen represents the kind of *concha anomia*, which

Moreton

Moreton calls by the name of *terebratula*, because the projecting beak is *bored* with a hole or cavity. All the various kinds of oysters, cockles, clams, muscles, &c. belong to the class of bivalvular shells.

Fig. 9. The *echinites*, or *fossil sea urchin*. One of the round sort is here figured, as the most regular; but they are of many other figures, as described above.

Fig. 10. A *spine*, or *prickle of the echinite*. These spines, which are of many forms, are sometimes found adhering to the shell on which they originally grew; sometimes they are found lying by the side of it; and very often they are scattered about by themselves in masses of stone, and in the chalk of the Chiltern Hill, especially that branch of it which runs from Surry through the middle of Kent, to the cliffs of Folkstone and Dover.

Fig. 11. A single joint of the *asteria*, or star-stone; called also *encrinus*, from an elegant delineation upon them, resembling a *lily*, or such like flower.

Fig. 12. A single joint of the *entrochus*, a cylindric body of the same kind with the former.

N. B. The figures of these two bodies, so magnified as to shew all their elegant signa-

tures, are represented in fig. 3. and fig. 4. of plate ix. Fig. 5. of the same plate is taken from a good specimen of a *star* of the *waren-vein*, found in a fissure between the sparry *septa* of the *ludus helmontii* of Sheepy Island.

Fig. 13. A fossil *crab* from Bengal. The crustaceous kinds are not so common as the shell fish in the fossil state; but Sheepy Island affords fossil crabs, lobsters, and tortoises. "Fossil crabs," as my learned and worthy friend Mr. Jacob has observed, "were extremely rare in England before the "publication of Dr. Hill's History of Fos-"sils;" but he tells us, that, since that time, thousands of specimens collected in Sheepy Island had passed through his own hands. Their size varies from that of a small bean to that of the common crab of the coast. See his Short View of the Fossils of Sheepy Island, annexed to the Plantæ Favershamienses, page 141. No crabs yet digged up in this country, at least none I have seen, are in such fair preservation as the fossil crab from Bengal.

Fig. 14. A fossil *shark's tooth*. Mr. Lhwyd denominates all fossils of this class *ichthyodontes*, and has given many figures of them. The fossil here figured was anciently called

glossopetra,

glossopetra, a tongue of stone, and supposed to be the petrified tongue of a serpent: but their substance shews what they are; and they are also sometimes found sticking in a fragment of the very jaw to which they belonged.

Fig. 15. The *bufonites,* or *toad-stone;* a name given to the fossil palates of certain fish. This specimen, with ridges and furrows so regularly disposed, is of the rarest sort. Others, instead of these ridges, have round and oval studs, covered with their proper enamel, and of different colours according to the mineral with which they are impregnated. I have one from Minorca, of a deep orange-colour. No fossil impression of a scaly fish is here added, because a remarkable one has already been given.

Fig. 16. The *belemnite,* vulgarly called the *thunder-bolt.* This is split to shew the construction of the *alveolus* described above, and by which it is related to the *orthoceratites,* or *straight ammonite.*

Fig. 17. Another fragment of a belemnite.

Fig. 18. The *pediculus marinus,* or *trilobated sea eruca;* a very rare fossil, chiefly found at Dudley in Worcestershire, and particularly

ticularly described in the Philosophical Transactions *.

Fig. 19. The same animal in its extended state.

The figures of some of the fossil fruits in Plate V. marked with the letters *a*, *b*, *c*, &c. are worthy of a more minute explanation than has yet been given of them. We are not sure that any one of these is from the native fruits of this country or climate. Some of them certainly were produced in very distant parts of the globe, which is indeed the case with most of the fossil remains in that curious repository, the cliffs of Sheepy Island.

a, is a fruit, the outward pulp of which being partly broken off, discovers the stone, with the orifice of the cavity that contained the kernel. When taken from the shore, it was of the substance of copperas, and partly solid: but as the vitriolic salts of the copperas proceeded to shoot, it cracked and mouldered away.

b, is a stone of some other fossil fruit.

c, is a fruit of a singular figure, which, by its appearance, seems to have belonged to a tree of the coniferous kind. In shape it

* Ann. 1750, No. 496, p. 598.

it has some little resemblance of the fruit called the *sand-box*, figured in Johnson's edition of Gerard, under the name of Baruce, p. 1550, fig. 13.

d, is some species of cocoa-nut, oblong and angular. In many specimens of this fossil from Sheepy Island, the longitudinal fibres or filaments of the coat which invested the shell, are plainly to be seen.

e, is a plumb, having the pulp of the fruit very fairly preserved, with the basis of its stalk.

f, is another petrified fruit, with its stone contained in it. I call it petrified, but its solidity is really from pyritical matter or copperas.

g, seems to be the cup of an acorn, or some other fruit of the like figure. There are bodies found with these which seem to have an alliance with the fossil fruits, but are really *fungitæ*, or fossil corallines, some of a discoid, others of a conoid figure. Besides these, there are many vegetable bodies in the fossil state found on the shores of Sheepy, more than can be specified, except by a writer treating professedly of the subject at large. Amongst these I have a petrified cast, with no pyritical matter in it, from a joint

a joint of the bamboo cane, on which the polish of the surface, and the impression of the fibres, is exactly preserved.

h, is the stone of some small fruit, probably of a cherry.

These, and all such others as are impregnated with the black pyritical matter, I attempted to preserve, by covering them with the best varnish I could procure; but, doubting the success, I made drawings of a few of the most curious while they were perfect. I am informed, that if I had baked them first to absolute dryness in a slow oven, and then at proper intervals given them fifteen or twenty coats of varnish, they might have been saved.

Among the various kinds of fossil plants, there is a tribe from the vegetable kingdom, to which no name has yet been given, or can be given with certainty, because some specimens disagree with others, and no vegetable yet known to us agrees accurately with any of them. Fragments of these have been pronounced to belong to the tail of the beaver; sometimes they have been taken for a part of the body of some squamous fish; and I fear I myself, in a former part of this Discourse, have described that as the body of

of a fossil salmon, which did really belong to one of this unknown tribe of vegetables.

When the stem of this fossil vegetable is entire, it is rarely cylindrical, but of a compressed elliptic form, so that the greater diameter of a transverse section is sometimes equal to more than twice or three times the lesser. We are not without a recent instance of this compressed form, in the trunk of what is called the *plank-tree*, which is wide and flat like a plank. The surface or bark of this fossil is marked with scales, and divided into rhombs, like the cone of the larch, or the fruit of the *ananas:* sometimes it appears as a rank of parallel reeds, in the instrument which is called *Pan's pipe;* and many specimens are crossed with joints, or marked with points in an exact quincuncial order. Of these I have given four figures in Plate I. of which, fig. 4. is a specimen of the squamous kind. Fig. 5. has the same scaly appearance in the stem, but it has the addition of leaves, like those of an *equisetum*, or the top of the branch of a pine tree, which demonstrate its relation to the vegetable kingdom. Fig. 6. is of that sort which resembles a rank of pipes. Fig. 7. has the punctures in the quincuncial order. A large specimen, several

several feet long, of some vegetable, nearly resembling fig. 4. in lineaments and colour, is preserved in the Woodwardian collection at Cambridge, and is thought to have been some species of the *euphorbium*, or *torch-thistle.*

A Note on Bolder Stones.

Stones worn to roundness by the trituration which very soon takes place when hard bodies are agitated together, and rolled about in water, are called *bolder stones.* I have heard it urged by a learned friend, that the dissolution of stone, though it were absurd not to allow it in a certain degree, could not have been general at the flood, because bolder stones, formed by trituration, are found included in other large masses of stone; consequently they were bolder stones before the flood, and if so, they underwent no dissolution.

It may be owing to my inexperience that I never met with any instance of bolder stones so included; unless indeed we are to take the *calculus compositus*, or *plumb-pudding stone,* for such an instance: but I would inquire, whether such productions were not posterior

posterior to the flood, and formed by some cause of consolidation and petrifaction, which may be operating in some cases to this day? That bolder stones should be formed of stony fragments by the currents of waters when they retired from the earth, is not improbable: there was time enough, and motion enough. That there are bolder stones lodged in the earth, the generation of which could not have been prior to the flood, is plain from their containing extraneous bodies within them, which were collected in consequence of the flood. The *cat-heads*, which include fossil plants, are bolder stones, with the marks of trituration upon them. The same is to be said of those round stones on the northern coast of Yorkshire, which contain the petrified *cornu ammonis*: and many of the vast nodules of Sheepy Island, which have the fossil *nautilus* within them, bear witness that they have suffered the like accident.

The formation of stone in consequence of the flood, argues a preceding dissolution. If nodules of flint had been prior to the flood, we should find them in the state of bolder stones; but I do not remember that I have met with any flint, in its proper bed, with the marks of trituration, which must have happened,

pened, if the flints we now have had been prior to the flood: therefore they were formed at the settlement of the earth from the diluvian waters, and if so, the matter of flint was at the flood in a state of solution, which is also shewn by the casts of flint moulded in the tenderest shells with a very small aperture.

The dissolution of stone at the deluge is a matter of such importance toward a right understanding of the natural history of the earth, and was so much insisted upon by Woodward, and seemingly so well supported, that I adopted it very early. He considers it largely in his Defence of the Natural History of the Earth, against Camerarius*; and proves it, first, from the testimony of the Scripture, which asserts an actual dissolution of the matter of the earth, in passages plainly referring to the deluge †. To these he adds many remarkable expressions from prophane authors, preserving a tradition of the same extraordinary fact; such as that of Manilius ‡, *natat orbis in ipso*, "the world is a float "within itself." Then he appeals to the marine bodies inclosed in stone and marble, which

* Part I. p. 61, &c.

† See Isaiah xxiv. 18, 19.

‡ Lib. iv.

which afford a physical demonstration that the particles of stone had been in a state of solution. Whether the effect was absolutely universal upon all the stone of the earth's body, he seems not to have determined. In one part of his Natural History of the Earth he is doubtful whether the dissolution was total, affirming no more than that it extended to the parts that constituted the matter of the earth, *if not quite down to the abyss, yet at least to the greatest depths we ever dig.* See p. 74. This alters the state of the case very much; for if it is considered that the depth to which we dig, when compared with the magnitude of the earth's globe, bears no greater a proportion to it than the thickness of the paper-gores pasted on an artificial globe of three feet in diameter; then the principle of *trituration*, together with the stony matter detached from the *soluble* parts of the earth, might furnish more than matter enough to involve all the marine productions which we now find inclosed in stone and marble; and thus bolder stones, which were such before the flood, might be lodged in stone formed after the flood.

A Specimen of Mr. Edward Lhwyd's Doctrine concerning the Origin of Marine Fossils, Shells, and Mineral Leaves.

As a sequel to the positive evidence of a deluge, which has arisen from the consideration of extraneous fossils; I shall exhibit what has been urged to the contrary by lithologists who were inclined to solve all these appearances by some other hypothesis. Of these Mr. Lhwyd may be reckoned the chief; who has delivered his sentiments in an epistle to Mr. Ray, from which I shall extract, as fairly as I can, the substance of his reasoning, referring the reader to the piece itself for farther satisfaction. Mr. Lhwyd, from his long application to the study of fossil bodies, was prepared to treat of the subject; and he has expressed himself in clear language, both Latin and English. Weak objections from such an author, who certainly was not a weak man, may have the same effect as additional positive proofs to confirm the doctrine above laid down. It is proper to observe, that I take the objections, not from the Latin epistle in the Lithophylacium, but from

4 Mr.

Mr. Lhwyd's own English, published in the Three Discourses of Mr. Ray, where he has much enlarged what he had before written in Latin.

Objection 1. *Marine shells, if they had been relics of the flood, could not have been lodged so deep in the earth, but would have been stranded on the surface of it.* Here the author begs the principle, that the diluvian waters only washed the surface of the earth, as a common flood washes the meadows, and leaves river-muscles upon the grass: whereas we have the demonstration of fact, that the matter of the earth was disturbed, if not totally, yet to a greater depth than our researches extend to. With the matter of the strata so disturbed, marine shells subsided, and were lodged with it at all depths.

Obj. 2. *Marine shells are found sticking to the roof and sides of lime-stone caves and grottos.* This no man ever saw, unless by the shores of the sea, within reach of the salt-water. They stick *in* the fractured stones of caverns, and may by accident partly project *from* them and be exposed; but they never adhere *to* a cavern in their petrified state by a lateral application, as he supposes. And whereas Mr. Lhwyd affirms that he has found

entrochi inclosed in *stalagmites*, an incrustation of modern date; it must be a fable, like the story he tells seriously in another place, of live shell-fish ploughed out of the ground.

Obj. 3. *Land animals are seldom found in the fossil state, though a deluge would have brought them in common with the productions of the sea.* If they are ever found, the objection is answered; because it is out of our power to pronounce how they ought to have been disposed of. They are so far from being uncommon, that they abound in some places, almost to an incredible degree, as we have seen above.

Obj. 4. *Some fossils, with the form of marine productions, are entirely of chrystal or stone, without any appearance of a shell.* They are so; but in this case they have the lineaments of the internal surface of the shell, which shews they were at first invested with it: and where the casts of the echini are imbedded in flint, the exact interval once occupied by the shell is left vacant; and then we have the internal lineaments upon the cast, and the external ones upon the matrix. If it happens, in some rare instances, that the convex stone has the external signatures, Mr. D'Acosta's solution

of that case, as above mentioned, is very satisfactory.

Obj. 5. *Living fish have been found in fossil shells, which could not have been lodged in the earth by the deluge.* Authors are brought in formally as witnesses to this wonderful fact. Brand, in his Description of Orkney, Zetland, &c. tells of a minister, who was told by a gentleman, that the plough, some five years before, had turned up live cockles, three quarters of a mile from the sea, which were dressed and eaten. To this another like account is added, of some workmen in Wales, who said they had found live muscles in gravel, as they were digging for the foundation of a house.

Obj. 6. *All the shells in a bed ought to be filled with one and the same kind of matter.* This is not necessary in any case; because shells, amidst the various revolutions at the deluge, might be impregnated in one bed, and shifted afterwards to another. But if the bed itself is of heterogeneous matter, the shells within it will partake of it differently. There is much stone which abounds with particles and veins of spar: from such a bed I have taken many of the small anomiæ; some entirely empty, some filled entirely

 with

with stone, some entirely with spar; as it would probably happen to different shells in such a situation. The *lapis syringoides* has some of its pipes in the same mass filled with blue clay stone, some with yellow spar, and some with the glittering pyritical matter of the marcasite; and thus it must have happened in numberless instances, when shells were lodged in a stratum of mixt matter.

Obj. 7. There are so many marine productions in the earth, that the deluge will not account for them. This objection demands a very deep and comprehensive calculation to support it, founded on an absolute knowlege of the state of the sea, and its inhabitants before the flood. The world is a very large place: the sea, as it now is, more than twice as large as the land; and the productions of the sea, within a given tract, vastly exceed those of the land. Besides, the deluge would scatter about the remains of all the successive generations from the creation of the world, in those kinds which are of a stony and durable substance, as the *entrochi*, of which some rocks in midland countries are almost wholly composed. Yet again, there are vast tracts of land, which are reported to be destitute of marine fossils; while

while in other parts they abound, but nowhere, that we know of, in such measure as to render the deluge an inadequate cause of the phenomenon.

Under this head, Mr. Lhywd has added, that *few single teeth of fish occur upon the sea shores; many in stone quarries.* There must be some good reason for this: but that reason is not properly of physical consideration. You may ride twenty miles without seeing the tooth or bone of a dead horse by the road side; but if you go to a proper place, you may find a pit which is full of them, where they were laid by design. Such differences afford no objection; because the strangeness of them arises from our ignorance, who neither see the hand nor know the designs of that Providence, which collects and disperses things according to its will and pleasure. Who can give any physical reason, why the bones of land animals should be found in such profusion about the shores of the Gulf of Venice, and so very rarely in other places? Who can shew us what drew together so many various productions within the little tract of Sheepy Island? Why does the hurricane sweep all away from Barbadoes, and leave the Island of Antigua

in a manner untouched? Effects may proceed immediately from some physical agent; but the circumstantials of time and place must be referred to an higher power, and philosophy must leave them as it finds them. There is a physical reason why teeth should be found where jaws are not found, and vertebræ where the other bones are wanting; because teeth are preserved by the hardness of their enamel, and vertebræ are more solid than the other bones.

Obj. 8. *Some remains of fish are but lineaments without substance.* True; but many fossil fish of the squamous kinds (which are here intended) have the substance along with the lineaments. I have a fossil fish on a white flaky slate, of which the vertebræ and the ribs are all strong and prominent. The fleshy substance of fish will revert almost entirely to water, and their bones are easily dissolved by an acid; whence they would be capable of every degree of compression and evanescence, according to the state they were in when imbedded, and the kind of the matter which received them: and the squamous fish, though flat and perished on the *Islebian* slate, (as even shells themselves are perished from stone in many instances,) are pre-

preserved and petrified at Sheepy Island in their whole bulk, and with all their bones, cartilages, and scales. It was hard to Mr. Lhwyd to conceive how there should be the lineaments of a fish without the vertebræ: but is it not much harder to conceive how there should be the lineaments, where there never was the fish to make them?

Obj. 9. *Many fossil shells cannot be matched with their correspondent natural shells.* But many more have been discovered than were known in Mr. Lhwyd's time. The *concha anomia*, both plain and striated, have been produced; the natural *encrinus* has appeared; time may bring to light many others: and if some should never be found, as belonging to deep and remote seas, from whence no accident can dislodge them, but such as amounts to a subversion of the earth's frame, no real objection can arise from such a defect: and it is possible some species of shells and vegetables may be lost.

Obj. 10. *Marine substances have been generated in the human intestines; and why not in the bowels of the earth, as well as in the bowels of the animal frame?* Supposing the fact, the consequence is not valid, unless the earth is an animal, with a stomach and guts

guts like a man. Stony concretions, in varicous vessels and the flexures of the small intestines, have represented, and that but rudely, the matter moulded in the cavity of some turbinated shells: and this, I presume, is all Mr. Lhwyd had to compare with fossil shells, whose testaceous covering is actually preserved, and all their minutest lineaments retained.

Obj. 11. *Subterraneous leaves are no remains of the flood, because they lie too deep; whereas the flood ought to have left them upon the surface of the ground.* The mud of a mill-pond many feet in depth, and not emptied of many years, has been observed to contain dead leaves, very fairly preserved, down to its bottom. Leaves, and all other light bodies of that sort, except cork, will sink when they are saturated with water. Those that sunk first were covered with the mud that succeeded in tract of time till they were buried very deep. Thus it was at the flood; allowing for the difference between the mud of a mill-pond and the mud of a fluid world. It is farther objected, that leaves and vegetable bodies ought to be found in lime-stone, as well as in iron-stone and coal-slate. But it is not true that the parts of

of vegetables are never found in lime-stone. I have picked rotten friable wood out of the heart of a lime-stone rock, and have some of it at this time. That lime-stone is as proper to preserve tender leaves and their impressions as coal-slate and iron-stone, Mr. Lhwyd has not attempted to prove: and the contrary is apparent; for many plants, preserved in iron-stone, were first impregnated with particles of iron now visible, which rendered their forms incorruptible; and the plants in coal-slate, by the blackness of their colour, were first embalmed by a bituminous oil. He says farther, that the fossil plants found in England ought to be of such plants as are proper to England. But this is no good consequence, if plants were eradicated and dismembered by the confusion of the deluge; the waters of which would transport to one region the productions of another. The reverse of Mr. Lhwyd's position is more reasonable. The native productions of a country, under the circumstances of the flood, could not be retained in that country but by accident: and the currents of the tides at this day are observed to flow across the parallels of latitude. The land animals and marine shells found here, are not those of Britain, but

but by reason of an accidental mixture with others; why then should the plants be so? Lastly, he draws a parallel between the insects in ambar, and the leaves of plants in coal-slate, and calls the insects *representations:* for, says he, if you suppose they were once living insects, you must *explain how they came so deep under ground, and afterwards how they got into their prison of ambar.* No: we would desire leave to explain *first,* how they got into ambar, and *afterwards* how they got so deep under ground.

Such were the objections of the ingenious Mr. Lhwyd, Keeper of the Ashmolean Museum at Oxford. They are not the objections of an ignorant man, but of a man in distress, who had a dislike to Woodward's plan, and was carried away by his zeal into strange opinions. It frequently happens, that those persons, for whom what is ordinary and reasonable is not good enough, are punished with an affection to absurdities and impossibilities. For let us now examine, what better original Mr. Lhwyd could assign to marine and other fossils than that of the deluge? This then is the hypothesis he would have substituted in its place—that invisible

invisible ova of fishes are carried by vapours from the sea into clouds, fall from thence in rain upon the earth, penetrate into stone, and live and grow under ground, having their generation in the places where we now find them: and that mineral leaves and fragments of vegetables are from the seeds of plants conveyed in like manner by winds and clouds from foreign countries, and washed down, to grow and increase in the lower parts of the earth *. If this be learning, happy and praise-worthy are the ignorant, who plough the earth, or mend shoes, or catch sprats; and know nothing of terrestrial fishes, and plants bred in coal mines from the clouds of the air!

* See Mr. Ray's three Discourses, 4th edit. p. 191; or epist. 6. of his Lithophyl. p. 136, edit. Huddesford.—*Hoc ut paucis expediam, dico suspicari me, qui ex mari feruntur vapores, &c.*

DIS-

DISCOURSE VIII.

On Physical Geography; or, the Natural History of the Earth.

I. ON THE FORMATION OF THE EARTH, THE DELUGE, AND THE TRACES OF IT ON THE EARTH'S SURFACE.

SOME learned men of our own country have invented theories of the earth widely differing from each other, and supported by no authority either of history or observation. Dr. Burnet, an ingenious theorist, and a great master of his pen, drew up a scheme of the first formation of the earth, and the deluge, founded in part upon the Mosaic cosmogony, but blended with many groundless conjectures of his own. Mr. Whiston, an eminent mathematician, pursued another path, and derived the waters of the flood from the access of a comet. His whole system reads much like a dream. No man in his sober senses would have ventured

tured to reveal it to the world, that the earth we inhabit was made out of the matter of a comet's atmosphere; that, on the first day of the deluge, a comet passed just before the body of the earth; and that all this was reasonable upon the ground of some new and wonderful discoveries in astronomy *. Dr. Halley, who unquestionably excelled as an astronomer and philosopher, attempted to account for the variations of the magnetic needle from a loose internal nucleus within the earth; and, in the prosecution of the speculation, conjectured, that the world we live upon may have *another habitable world within it*, surrounded by a system of subterraneous luminaries, similar to those which give light to the upper earth, but comprehended within a smaller sphere.

He was of opinion, that the supposition of such a planetary heaven under ground would account for the difference between the specific gravities of the earth and moon. It will scarcely be credited, that any author could seriously advance such a wild hypothesis: but mathematical vanity hath its legends, and can be as credulous, upon occasion,

* See his New Theory of the Earth, book ii. prop. 1 and 10.

sion, as the vanity of superstition. The paper in which Dr. Halley proposed this theory, is printed in a volume intitled Miscellanea Curiosa, p. 43, &c.

When Dr. Woodward had published his Observations on the Natural History of the Earth, an Italian author set himself to refute them with all his might, and accounted for them upon an opposite principle. Woodward derived the great changes in the earth from *water:* this writer excluded the effect of water, and ascribed every thing to subterraneous *fire*. All mountains, according to him, were raised out of the sea, as the Island of Santorini in the Archipelago; and thus, says he, it came to pass, that we find the productions of the sea in mountains! Another writer thinks this system ought to prevail against Woodward's, and would do so, but for certain popular prejudices*!

I assure myself the learned reader will agree with me, that no one of these schemes are worth a serious confutation: nor is it my business here to confute falsehood, but to follow the truth as nearly as I can. If these theorists, so learned and ingenious, have failed

* The reader may see more of this in vol. x. Trans. Abr. p. 614, &c.

failed so egregiously by trusting to their own imaginations, let us take warning by their example, and proceed upon the best authority, which is that of revelation; endeavouring to explain it in such a manner as to keep within the laws of experiment and observation, as far as a case so extraordinary will permit. The first formation of the earth, and the mode of overflowing it afterwards with water, are subjects of which we can have no knowledge from reason or philosophy; in which case, it would be ridiculous to refuse such helps as are held out to us, and mispend our time and thoughts in preferring the worse to the better; which is in effect to feed upon acorns, when the fields are covered with corn. If the earth was formed by a miracle, and drowned by a miracle, let us not disdain to take what information we can get from that book which is a history of miracles, and the only authentic one in the world. Why did Dr. Woodward write more clearly upon these things than any body had done before him, but because he took the inspired light for his guide? So far as he was a commentator upon a text, he might fail, though his plan might be right upon the whole: on which consideration, whoever follows his example should

warn the reader not to charge the foundation, with those mistakes which are to be found only in the superstructure.

In the progress of the formation, the earth appeared under three different states; the first of which was its *chaotic* state; the second, its state of consolidation; the third, its habitable state, when it appeared similar to what we see at present. Of these three in their order; and, first, of the chaotic state.

Chaotic State of the Earth.

Upon its first creation, the earth was void and without form: it contained what the poet calls the *discordia semina rerum*, both earth and water in one fluid mass, which had neither the solidity of earth nor the fluidity of water; *instabilis terra, innabilis unda.* These rudiments of the world were disposed in the form of a sphere, which was *void* or hollow within; and being so, would contain within it the same kind of matter which is said to have surrounded it, when *darkness*, that is, gross palpable air, (which the poet calls *lucis egens aer,*) lay *upon the face of the deep.* Thus we see the chaotic earth subsisting at first in three concentric spheres; the

the innermost of which consisted of the unformed matter of the element of air; the second was a fluid mass, with all the solid matter of the earth floating in it; the third was what we now call the atmosphere, the same for substance with that which filled the internal void, and upon which, as we shall see, the mechanism of the subsequent formation very much depended. This state of the earth is represented in plate III. fig. 3.

The Intermediate State.

The second state of the earth was brought on by the formation of *light*. When light and air are mixed together, as in the element wherein we now live and breathe, the air becomes elastic, and the light penetrates all things. This elastic medium of light and air constitutes what is called the *firmament;* which term has an unfortunate effect in the English, because it induces ignorant readers to suppose, that the firmament, from its name, must be something *firm*, solid, and immoveable: and there is the same difficulty in the Greek of the Septuagint, στερεωμα. The *firmament* is called by the name of *heaven*, and birds are said to fly in this *firmament of heaven:* the firmament is therefore

fore the medium of air and light in *expansion*. When light was first put into action, it would penetrate to the interior parts of the chaotic sphere; and, mixing with the internal air, an elastic medium, would exert a force of compression from within and from without: by means of which, a *separation* would take place in the mixt matter of the deep; the solid parts would be driven together near the middle region of the deep; and the waters, being forsaken by the solid matter, would form two concentric spheres, the one above, the other below it. That water should be below earth, is contrary to the Aristotelian doctrine, which placed the elements in the exact order of gravity and levity: but all things conspire to shew us it is so now. Even fire, which is lightest of all the elements, is found under the earth; it could not otherwise come up from it, as it does every day. This state of the earth is expressed in the next figure, plate III. fig. 4.

The Habitable State.

For bringing the earth to its third, or habitable state, the waters are said to have been *gathered into one place*, so that the *dry land* might *appear*. Hence it follows, that the

the upper waters were gathered to the under, not the under to the upper; because *that* surface of the solid earth was exposed and dried, which lay outermost, or next the atmosphere. This indeed is so obvious, that it is needless to enlarge upon it. But then, as the solid earth would, from the method of its formation, be so entire as to leave no passage for the waters to communicate with each other, a certain force must have been applied to make a way for the upper waters to pass to those that were underneath. This force broke the shell of earth in various places, as the Creator was pleased to direct it, and produced that mixture of land and sea, which made the waters navigable, and the earth habitable. This could not be brought to pass without forcing out some of the air contained in the void space under the earth; which would come up as the waters went down, in equal quantity. Unless this interchange had happened, there could have been no room to receive them: waters cannot retire into a space containing air, without first driving out the air in a contrary direction. When the upper waters joined the lower, and formed one body, they subsided, till what remained of them stood upon

a level with the land; subject to no farther change, but that of rising and falling in tides, according to the established laws of nature. Many of those apertures, through which the waters passed, when a force from above drove them downwards, would be stopped up with the earth and rubbish carried into them; and others would remain open, to keep up a communication between the waters which are visible in the seas of the earth, and those that are invisible in the abyss below it. Besides this, the solid matter of the earth, as it tended to dryness, would necessarily shrink into a lesser compass; and leave many fissures, veins and caverns; some of which would be dry, or subject only to damps and vapours; while others would be filled with water, and furnish streams for springs and rivers. Some of these chasms would open outwards, towards the air; and others would be more spacious within, while they were closed at the surface. Such we suppose the antediluvian earth to have been; much like what it is at present, though probably with a much greater proportion of land; a soil much more rich and fruitful; an air much more serene and temperate: for the curse, which changed

changed all these things, did not take place till the deluge. That the earth was not one smooth uninterrupted plain, as Burnet has supposed, is evident from the sacred account, which tells us, there were *high mountains* to be covered by the *waters* of the flood; and also from the nature of the thing itself, mountains being necessary to the production of springs and rivers. This form of the earth is represented in the 5th fig. of plate III.

The Deluge accounted for on the foregoing Principles.

With these principles we are prepared to consider the flood, which will now admit of a more easy and natural solution. We are told, it was brought to pass by the breaking up of the *fountains of the great deep*, and by opening the *windows of heaven*, and by the descending of the rain. It is easy enough to understand what is meant by the *fountains of the great deep:* they were the passages through which the waters had retired downwards into the abyss at the creation, and were now opened again to let them out upon the earth. But here we are to note, that water never can ascend upwards, without the force

of some agent previously acting downwards: neither would the waters leave a vacuum behind them when they came out of the earth; as they came up, some other substance would go down to supply their place; or rather they came up by some passages, because that substance was forced down by others to expel them; for the elements are always used to act upon one another, so far as they will go, for the production even of such effects as are miraculous. There are three ways of forcing water upwards: the one is by an incumbent weight, such as that which results from the height of a reservoir: another is, by the rarefaction of confined air; and a third, by the condensation of air; that is, by the forcing of more air into a confined space, the expansive power or elasticity of which will force out the water. The air is an agent adequate to any effect of this kind, when it is made to exert its utmost power. We read of a *great and strong wind which rent the mountains, and broke in pieces the rocks* *. We suppose then that the air was driven downwards, for this purpose, through those passages which are called *windows of heaven*. These may seem very obscure terms to express

* 1 Kings, xix.

press such a sense by; but *heaven* is the *firmament*, or expanded substance of the atmosphere; and *windows*, as they are here called, are holes or channels of any kind. The same word is used for *chimnies*, through which smoke passes: and for the *holes*, probably cliffs of a rock, in which the doves of the eastern countries have their habitation: so that the terms are capable of that sense which the reason of the thing seems to require. If the substance of the air was forced through those chasms of the earth which opened towards the sky, and might be called the *skylights* of the earth; then, of course, the water must be expelled or raised through the *fountains of the deep*, or those lower chasms whose orifices opened into the waters below; which would be extended and broken up by the violent flux of the waters toward the surface. If we add to this, the impetuous rains and storms which descended at the same time from the sky, we have a scene tremendous beyond all description: the air rushing furiously down with a roaring noise into the bowels of the earth, and rending the rocks in its passage; the waters spouting upwards in vast columns towards the sky, as fire from a volcano, and meeting the stormy rain which

which fell in water-spouts or cataracts from the clouds; while a pitchy darkness prevailed over the whole face of the earth, from the absence of the sun and the lights of heaven. In consequence of these terrible convulsions of nature, the substance of the earth was torn to pieces, and reduced to its primitive chaos; all living creatures were destroyed, except those in the ark; all vegetables were displaced; and the productions of the whole earth floated about in one universal wreck.

The Reformation after the Deluge.

When the purpose of Providence was brought to pass, a reformation of the earth took place, similar to its first formation: the solid matter settled into orderly strata; the waters descended, as before, through the like apertures in the earth; the subterraneous air was restored to the atmosphere; the earth was parted into seas, continents, and islands; and its surface was dried by a mighty *wind*, which *passed over* it* for that purpose.

Central Nucleus.

When the strata of the earth were broken through, and the waters returned to the abyss,

* Gen. viii. 1.

abyss, they would necessarily tear away and carry down with them a vast quantity of the solid matter of the earth; which being carried to the central parts, would there form a *nucleus*, which even now may have considerable effects in producing some phænomena, not well to be accounted for on any other principle. Dr. Halley judged it necessary to have recourse to some such moveable mass of matter within the earth, to account for the revolution of the magnetic variation: and it is possible such a body may have great effects upon the tides and currents of the ocean; for the earth being subject to the influences of the heavenly bodies, many effects observable below may have their stated times and periods, corresponding with the motions of the heavens.

When it was said above, that, after the dissolution by the flood, the solid matter settled into orderly strata, it was not meant that they settled in the order of their gravity; and there was a reason why it should not be so. In the account of the formation, we have derived the consolidation of the earth from two opposite forces; and it does not appear how it could be effected otherwise. From hence we may account for a very difficult phænomenon,

menon, with which all naturalists have been greatly perplexed. The strata which compose the body of the earth, are not in the order of their specific gravities; sometimes the order is quite retrograde, the lighter being in succession below the heavier. Now, if only one cause had acted upon this occasion, such a phænomenon might seem to contradict the laws of nature; but if the matter to be consolidated was between two powers, they might prevail alternately, with a kind of oscillation, and produce that seeming disorder which appears so unaccountable. The action of a power *from* the centre, as well as *towards* it, was necessary on this consideration; that otherwise, the spherical strata, which are now at the bottom of the settlement, could never have been stopped, so as to form an *internal arch*, to cover the waters of the abyss, but must have gone to the centre. That two such powers, acting on a shell or crust of matter, are possible in nature, is plainly demonstrated by the experiments of electricity. Woodward argued, that gravity must have been suspended when the strata settled; and certainly it was so, if, as we have said, there was another force acting in opposition to it. Some philosophers (Dr. Halley among the rest)

rest) have found it necessary to allow, that to this day there is, in a certain degree, a *conatus against gravity*, from those steams and exhalations which arise within the bowels of the earth; by means of which, vegetables have their growth *upwards*, and clouds, of a specific weight, superior to the air, are carried aloft into the atmosphere.

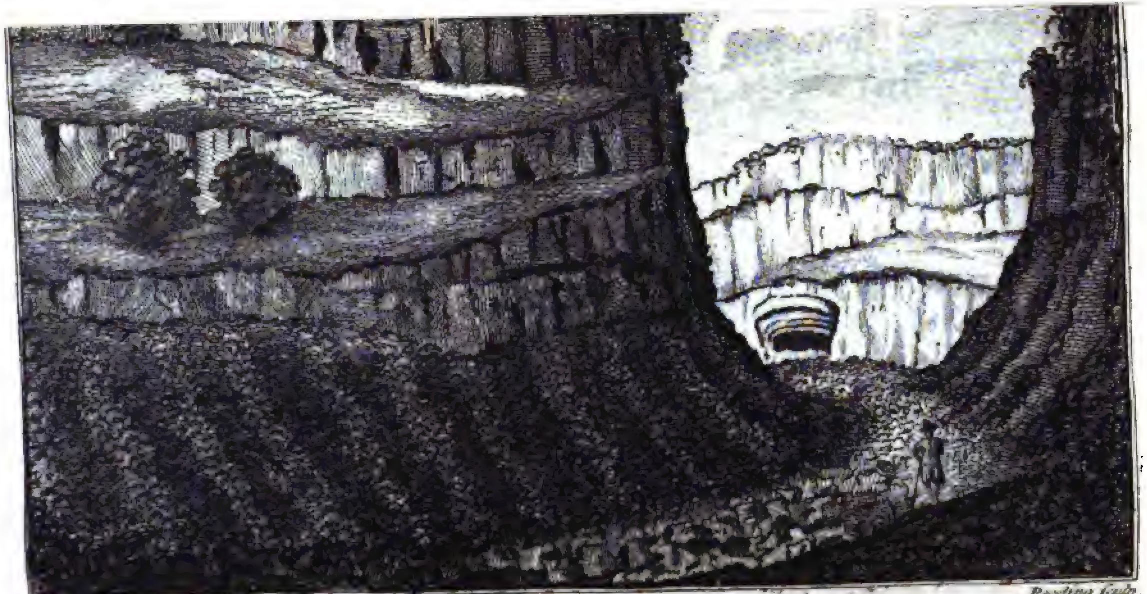
New Earth not so good as the Old.

As the deluge was undoubtedly inflicted for a curse upon the earth, the opinion of Dr. Woodward is very probable; viz. that large quantities of that vegetable soil which makes the earth fruitful, was swept away from the surface, and carried down by the waters; so that the earth is now in an impoverished condition, much less able to provide for its inhabitants than in the ages before the flood. In some parts, this matter lies deep, and is inexhaustible; but in most countries it is but thinly spread upon the surface, while in others it is in a manner entirely carried off; so that the barren soil which remains is scarcely productive of common verdure. Another learned author, once a fellow-labourer of Dr. Woodward, makes the following very learned and probable conjecture: that

wards; but if this were the case, no hill could be composed, as multitudes are, of horizontal strata. Vallies are of such a figure, their sides gradually sloping, their course turning and winding like the course of a river, as plainly shews them to have been formed by the descent of water. A sudden and violent fall of rain in a thunder shower, will frequently produce the same effect in a lesser compass, tearing away the earth, and forming channels through the fields, with such flexures, and in such directions, as the water would naturally take in pursuing its way from the higher to the lower parts.

I have received great pleasure in observing the courses and communications of the vallies in the mountainous country of Derbyshire; how they begin gradually, with an easy descent from the higher grounds; growing deeper as they proceed farther; the larger ones receiving many smaller, which join them in their progress; till at length the furrow becomes deep and rugged, its sides consisting of ragged cliffs and precipices, its bottom covered with loose rubbish and fragments of rocks, till it terminates in some greater channel, or falls into the bed of a river, or leads to

some



H. Lowe delin.

Rosling sculp.

some place where there was an aperture (now closed up with rubbish) through which the waters of the flood were discharged into the subterraneous regions. Such a valley exhibits all these evidences, which it naturally must, if it was formed by a vast body of water descending with an accelerated velocity till it tore away all the soluble parts, and left nothing behind but what the stream could carry no farther. I have represented a scene of this sort in two drawings, as it appeared to me upon the spot. See plate viii. fig. 1 and 2. The first of these views expresses the commencement of a valley in the Peak of Derbyshire, not far from the 157th mile-stone, on the road from Matlock to Buxton; and the face of the country shews how the earth is furrowed by other lesser declivities, which join the great one. The verge of the prospect which leads the eye to this channel, as to its centre or bottom, may be at least forty miles in circumference. The second shews the appearance of the main channel of the same valley, above a mile below the entrance, where the naked rocks are so steep that little can be seen but the sky over our heads; and the bottom is covered with fragments of rocks and rubbish from the superior

perior strata. A spectator of this rugged scene, placed at such a depth amidst the ruins of the earth, is struck with a sense of solitude which no words can describe: he seems to himself to be cut off from the habitable world, and removed to the tombs of the dead, or the visionary regions of departed spirits. The face of the earth abounds with other vast furrows of the same kind. In rocky countries, these vallies are rough and ghastly; but where the soil is softer, the cavities are gradual, and the bottom is rich with the vegetable matter abraded and carried down from the higher grounds.

This elegant serpentine disposition of vallies, occasioned by the descent of water, constitutes the chief beauty of a prospect: such a cause would be productive of that *line of beauty*, which is so much admired in the natural windings of a river, and which art, if it would please the eye, must be careful to imitate, but still with a proper mixture of variety; for nature never yet made two vallies alike. From all this it is still farther evident, that the agent which formed the mountains acted *downwards*, and not *upwards*. The highest parts of a country are generally those most remote from the sea. There we observe

either ridges of inland mountains, or high and extensive plains, from whence furrows are formed with a gradual descent, increasing into dales, and those dales falling into larger vallies, which open into a declining country, adjoining to the shelving bed of the ocean.

Present Surface of the Earth indicates a past Descent of a vast Body of Waters.

Such a regularity never could have prevailed, if mountains had been generated either by a violent elevation or depression of the strata; and therefore all hypotheses which suppose any such thing, whether of Whiston, Burnet, or Woodward, are contradicted by the face of nature. But worst of all is the conjecture of those who would derive all the mountains of the world from volcanos. In the world at large, we see every where the traces of descending water; but *their* fancy leads them to search for nothing but the explosions of fire. That fire has made many alterations in certain places, more than it is vulgarly believed to have done, we ought not to deny; but these are comparatively nothing, when they are compared with the vast and universal effects of the diluvian waters. These effects may be followed beyond the

visible surface of the earth; for the ocean has its hills, its vallies, its precipices, far beneath the surface of its waters; and therefore the waters which retired from the land had still a deeper road to find below the level of the ocean: they would act with more force as they ran lower; whence it may be inferred, that if the vast bed of the sea could be exposed to view, we should find it more irregularly furrowed in many parts than the surface of the land. There we should see vallies and chasms which have no bottom..

We generally impute the effects of the diluvian waters, when they retreated from the surface, to their weight and accelerated motion, from the common force of gravity: but there is reason to think, that the *wind* which was *made to pass over the earth* (Gen. viii. 1.) after the flood, was of such a sort as to impel the waters at the proper parts, and add greatly to their effects upon the solid parts of the earth. An agent, such as the wind is, which of itself can rend mountains and rocks, must have performed strange things when it cooperated with the force of water. The wind of a common storm dashing the waves against the cliffs near the shore, works upon the earth with such violence, and undermines it in such

such a manner, as to produce wonderful changes in a short time; of which any spectator may have a specimen, who surveys the state of the cliffs at Harwich in Essex, and Sheepy Island on the coast of Kent.

Present Water-ways were first opened by Water.

When we survey the rivers and water-courses of the habitable world, we cannot but see how necessary it was that the vallies of the earth should derive their figure and their concavity from the currents of a flood. Many of them were undoubtedly designed for the conducting of streams and rivers; and where water hath once made its way, other waters may follow, flowing naturally through the successive declivities which nature has opened for them; and so emptying themselves either into larger streams, or proceeding onwards till they have fallen down to the level of the ocean. It does not appear how any such provision would have been made, if mountains had been formed by an elevation of the strata: many basins would have occurred with no regular outlet, where the water of springs would have been accumulated and dammed up to no purpose. Some

such instances may have been owing to other causes, in consequence of which lakes have been generated where we now see them; but the water-courses of the earth could have been disposed as they are by no other general cause than a previous descent of water, forcing a way for itself, and leaving a passage open for all the water that was to follow to the end of the world.

Pebbles and Fragments of Stone on the Sides of Mountains.

We have another proof of the descent of waters from the earth, in that multitude of pebbles and fragments of stones, worn to roundness, which are dispersed upon the sides of mountains and inland eminences, especially such as consist of solid strata or hard rock within, and have long flats or level grounds at their tops. These are found from two or three inches in circumference, to eight or ten feet; and are most remarkable on the sides of some high lands in South Wales, and in several of our western counties. The same occurs on the ridges of the high hills of the North, as also in Cornwall; neither are the Alps without them, where no river can be supposed to have reached to wear them to such

smoothness,

smoothness, and give them their round figure. Wherever they are now found, they must once have been rolled about and rounded by currents of water. A learned naturalist observed, that the rounded pebbles scattered over the country between the Alps and the Danube, are of the same kind of stone with that which lies in the solid rocks of the Tyrolensian Alps at a vast distance, and from whence they must have been conveyed to the place where they are now found. The farther they were carried, and the more they were rolled, the more they were rounded and lessened: on the mountains of Sweden the same kind of stones are found, much worn, and as it were polished, and mixed with sand. Even that vast quantity of sand which is found in and near mountains, carries evident marks that it has undergone some remarkable trituration, which has taken off its angles; like that upon the sea-shores, which is daily agitated and ground by the motion of the tides.

II. On the External Figure of the Earth.

Philosophers have reasoned *à priori*, that a spherical figure is of all others the most con-

 venient

venient for the earth, on many considerations, as an habitable world, and that it is the most natural; forasmuch as any body, exposed to forces which tend toward a common centre, as the earth confessedly is, must assume a round figure. Observation abundantly confirms this: for, first, the earth is observed to cast a conical shadow into the heavens, through which the moon passes in lunar eclipses. The line that bounds the earth's shadow is always distinguishable upon the moon's body as a segment of a circle. Secondly, the horizontal refraction of the atmosphere, by which the heavenly bodies are affected, is so nearly the same in all directions, that is in all azimuths, that the extent of the atmosphere is equal every way from the point of the spectator; which could not happen but upon a spherical surface. Thirdly, it is farther demonstrated by observing the altitude of any star upon the meridian; for if the spectator changes his place in the direction of the meridian, he will discover that equal distances upon the earth produce equal changes in the heaven; which could not happen but upon a spherical surface. Fourthly, we have a more palpable proof of this from the appearance of objects upon the earth or sea; because,

cause, as we depart from them upon the water, they seem to subside gradually below the visible horizon; whence it is evident that there is an intervening convexity. Ships at a distance upon the water are not visible in their hulls; at a greater distance their mainsails disappear; and at a greater still, their topsails: which could not be if they sailed upon a plane. But the truth of this doctrine is most evident and even palpable from the circumnavigation of the world. Ships have gone out to the westward, and have come home from the eastward. This was a stupendous performance when it was first accomplished; but several navigators have done it of late years in no very great tract of time.

Magnitude of the Earth's Globe.

The magnitude of the earth's globe is discovered by celestial observations. The circle of the heavens is divided by astronomers into 360 degrees; therefore, if it be found what portion of the meridian upon the earth's surface corresponds to one degree in the heavens, that must be $\frac{1}{360}$ part of the earth's circumference. Such a portion has been actually measured, and is found to contain about 69½ English statute miles; which being

ing multiplied by 360, makes the whole circumference near 25,000 miles, its diameter 8000, its semi-diameter 4000; if we speak in round numbers. The mensuration of the earth's magnitude is a problem, which in all probability has exercised the wit and skill of geometricians in all ages of the world. If the reader wishes to see a farther account of what has been done in this way, I would refer him to Dr. Long's Astronomy, page 125, &c. or to the conclusion of the last edition of Stone's Translation of Bion, p. 318.

It ought to be Spheroidical, from Physical Causes.

It appears from observation, that the earth, though we call it a sphere, and, generally speaking, it may be taken for such, is not exactly spherical, but spheroidical; and that the axis is somewhat less than the diameter at the equator; so that the earth is an *oblate* spheroid. Philosophers have different methods of accounting for this figure; but, without any deep researches, it seems to result naturally from the circumstances which attend the earth and its constitution. If the matter of the earth were disposed in a fluid sphere, and then consolidated by pressure, it would

would assume a form which bore a certain relation to the forces that acted upon it. If it was every where acted upon by equal forces, the result would have been a perfect sphere: but as the forces must have been unequal, the consequence must be an inequality in its figure. The equatorial parts would necessarily be exposed to a greater degree of heat; they would therefore be *rarefied:* and the polar parts being subjected to a colder medium would be more compressed; in consequence of which, the polar diameter would be shorter than the equatorial: and this consequence seems absolutely necessary. It would be unphilosophical to suppose that the earth could be equally affected in all parts, when it is so unequally circumstanced; and it would be still more so, to suppose that the elements, which invest it, had no effect upon its constitution. The exposure of the earth's orb to the sun is a *datum* from whence some difference must arise in the several parts of it. The barometer teaches us, that a greater weight is at all times incumbent upon the polar regions at a distance from the sun, than upon the equatorial regions, which are nearer to it.

I do not deny that other causes might

conspire

conspire to the same effect: the earth, while in a fluid form, and subject to a diurnal rotation, might be affected by a centrifugal force, from whence the great Newton has deduced its spheroidical figure; but the like figure seems to follow as necessarily from other principles, and I think, with submission to such great authority, that we should never treat of this globe, as if it were exposed to certain artificial forces, independent of the natural forces of the *elements*, in which it is involved, and by which it is governed. It is also well known, that there is a constant draught in the atmosphere, from the poles towards the equator; and if the same prevailed during the consolidation of the earth at its formation, or reformation, there would follow an accumulation of matter toward the equator. Something of this kind may happen in a small degree to this very day: the equator will rather be gaining from the poles, than the poles from the equator.

Thus much however is certain from the fact, that, let us assume what principles we please, whether the centrifugal force of Sir Isaac Newton, or the natural forces of the circumambient elements, it appears, and is allowed on all hands, that the whole earth

was

was originally in a fluid state: and hence a late writer has very ingeniously deduced and demonstrated the primæval *fluidity** of the earth: though it was also deducible from other phænomena, as that author allows †. The *difference* between the equatorial and polar dimensions, when compared with the earth's semidiameter, is but an inconsiderable quantity, not amounting in the whole to an elevation of more than 16½ miles out of 3970; that is, to less than a 240th part of the distance from the surface of the earth to the centre. If a meridional section of such a spheroid were laid down upon paper, the eye could not distinguish it from a perfect circle; and if the body of the moon is supposed

* See Whitehurst's Inquiry into the original State and Formation of the Earth, pages 8, 9.

† "The beds of argillaceous stone, &c. incumbent on coal, contain a great variety of figured fossils, representing different species of the vegetable creation. Phænomena of this nature plainly evince that all such beds of stone must have been originally in a state of fluidity, to receive the bodies thus entombed." Page 16.

This fact does not evince a *primæval*, but a fluidity *subsequent* to that of the primitive chaos; because the plants so entombed muſt have belonged to the earth in a formed and perfect state. The *spheroidity* of the earth is a better argument of its primæval fluidity.

posed to deviate from a sphere in this proportion, I think no instrument could possibly ascertain it.

The ingenious Mr. Maclaurin, than whom nobody understood Newton's principles more exactly, or explained them more clearly, has given a concise description of his theory of the earth's spheroidity, deduced from the principles of gravity, in B. 4. C. 6. of his learned account of Sir Isaac's philosophical discoveries, which the reader may consult; and he cannot consult it without admiring the ingenuity of it, as it affords us a superior instance of his profound sagacity and skill in calculation. Whether some allowance ought not to be taken into this theory, for the concurrence of other causes beside that of a centrifugal force, especially for the effect of the moon upon the equatorial parts of the earth, which, in its fluid state after the deluge, must in all probability have been considerable, I leave to be examined by those who have thought more deeply on these matters. As it is the nature of a centrifugal force to carry the heaviest bodies farthest from the centre, while those which are lighter are thereby impelled nearer to the centre, it does not appear how a greater solidity *there* than at

at the surface can consist with the action of a centrifugal force.

Incommensurability throughout the Works of Nature.

I have often reflected upon it with wonder, that wherever we look for equalities and commensurabilities in nature, we are always disappointed. The earth is spherical, but not accurately so: the summer is unequal, compared with the winter: the ecliptic disagrees with the equator, and never cuts it twice in the same equinoctial point: the orbit of the earth has an eccentricity more than double in proportion to the spheroidity of its globe: no number of the revolutions of the moon coincide with any number of the revolutions of the earth in its orbit: no two of the planets measure one another: and thus it is wherever we turn our thoughts, so different are the views of the Creator from our narrow conception of things! when we look for commensuration, variety and infinity occur to us instead of it.

III. Of the Internal Disposition of the Earth.

The solid matter of the earth is divided into *strata* or layers, which are of different sorts, and of a different thickness, from an inch or less to an hundred fathoms; and have in general a concentric arrangement. When we have supposed all this matter in a state of solution, as in the chaos, and would bring the parts together each to its like, we are tempted to form hypotheses *à priori*, founded on the common phænomenon of gravity: whence it would follow, that the heaviest strata should be lowest in order, and the lightest uppermost. But the strata of the earth have an arrangement not consistent with this hypothesis. We have hard stone at eighty or an hundred fathoms deep; above that, a seam of coal; then above that, perhaps, twenty fathoms of stone, then another seam of coal, and so on: the coals with scarce a grain of stone in them; and the strata of stone with scarce a grain of coal in them; and the different sorts of stone exactly sorted. The lightest leaves of vegetables are found all together, above a seam of coal, with vast masses

masses of stone lying above them. Sea shells are found in beds together; sometimes under stone, sometimes above it; sometimes in the midst of it. Clay, chiver, slate, and such like, are sometimes in strata nearly as thin as paper, and succeed one another in every order that can be imagined; that is, (to our thinking,) in the greatest *diſorder*. In the lightest state of chalk, we find the nodules of pyrites, which are almost as heavy as iron; and ore of lead, almost as close and heavy as after its fusion, intermixed with spar and other light matter: and throughout the interior part of the earth, if we had opportunities of examining the whole, I suppose there is not one single instance to be met with, where the strata are placed in the order of their specific gravities; so that their arrangement is a problem not to be solved on the hypothesis of gravity. The formation of a crust of tartar in all directions round the sides of a wine cask, is an effect more nearly allied to the arrangement of the parts in the strata of the earth, than the descent of solid parts in a fluid by the power of gravity.

When we say, in general, that the matter of the earth has a concentric arrangement, some exception must be made for the parts

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of metals; which are not only deposited in veins intermixed with the strata, but are also lodged in the perpendicular and oblique cracks or fissures between the strata, whitherto they were conveyed after the strata had settled: for the strata could not be cracked and parted asunder till they were first formed.

The science is very useful and valuable, which teaches how to discover and pursue the veins of metals, minerals, coal, &c. in the beds where nature has lodged them. Indeed these cracks themselves, which occur every where, and in all matter, are of great consideration; for unless the strata had been thus naturally parted by multitudes of cliffs and fissures, all the art of man, and all the force of gunpowder, would not have been sufficient to have extracted masses of stone from their beds for the common uses of life. The rules observed by miners are too particular to be here enumerated and described; but there is one which may be easily understood. When the continuity of the strata is interrupted by a fracture, the strata are thrown out of that horizontal position which is natural to them, and make an angle with the horizon; which may be called the angle

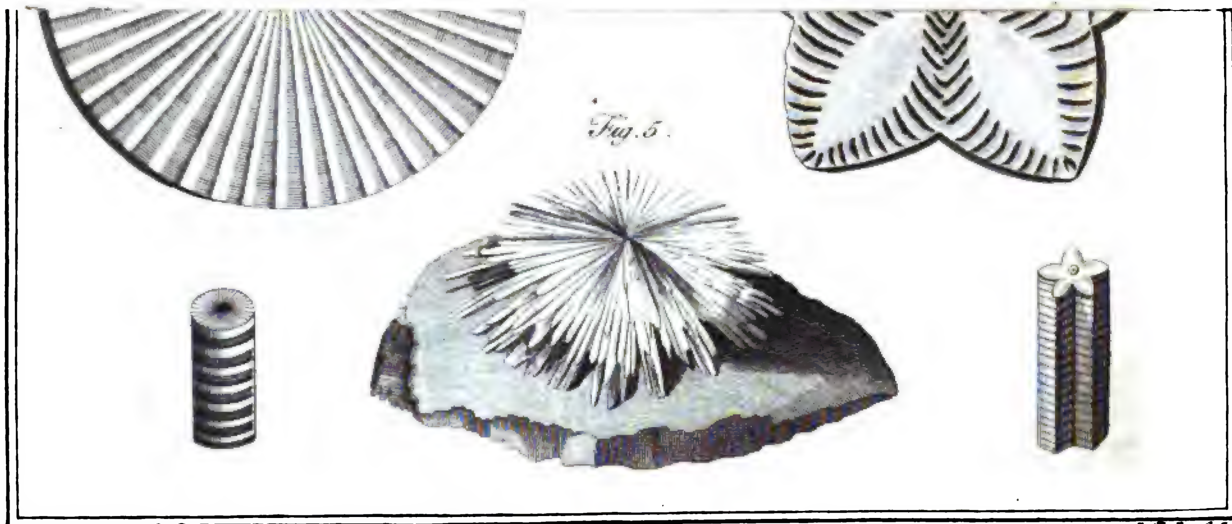

Fig. 5.

Jn. Lodge sculp.

of their elevation or depression; the miners call it their *dip*. In this case, if the succession of strata is accurately noted on one side of the fracture, where a vein of coal or metal is found amongst them, it may thence be learned where the same vein will occur again on the other side of the fracture; because it will be found adjacent to the same strata as before. When the edges of the strata on each side a fissure are thus parted and mismatched, they are said to *trap*; and the space between them is filled up with rubble, or stones, or minerals, &c. Sometimes these fissures are the richest parts of the soil, containing such matters as are not to be found elsewhere *. In fig. I. plate IX. F represents the fissure, by which the strata are parted,

 and

* Some of the fissures in Cornwall are near twenty feet over, and commonly full, or near it, of metallic and mineral matter. The fissures at the greatest depth are generally largest: as we ascend, they become gradually less, but more frequent and numerous: insomuch that were the globe divided in two, and the strata viewed upon the face of the section, the figures would appear after the manner of a tree: at the bottom a large trunk, which, higher up, is divided into branches, which break into lesser, and at the top into twigs. But the branches are not contained in a straight line: they start afresh, at some little distance on one side, as in fig. 2. plate ix. that by an intervening boundary the metallic matter

and which is filled up with extraneous rubbish, carried in after the strata were parted. The black vein of coal on the left side, is found with five other strata above it; but being interrupted by the fissure F, where it *comes out to the day*, the stratum of sand, No. 4, on the right side, by reason of the trapping, is found opposite to it: thence it is to be collected, that the fourth stratum below that sand will be coal; and when the angle of the *dip* is observed, it may be known where to sink a pit, and where the coal will again appear to the day, provided the figure of the surface of the ground will permit it to shew itself. When I was once at the bottom of a lead mine in Derbyshire, a miner informed me, that the veins of the metal always make a greater angle with the horizon than the sides of the mountain do, in which they are found and come out to the day; which was probably occasioned by the descent of the waters of the flood, tearing away much of the matter from the summit, and lodging it upon the sides and in the vallies beneath, after the strata had received their inclination.

Origin

matter might be detained in its descent, and prevented from sinking away to the bottom of the earth. See Mr. Hutchinson's Observations in the year 1706, p. 316, 317.

Origin of Subterraneous Caverns.

In parts where the soil abounds with rock to great depths, the strata are apt to be much dislocated; and besides their various inclination, they are subject to another accident: for where the arch at the top, being very strong, has preserved itself entire, or nearly so, while there was a dislocation or settlement of the rock underneath, caverns are formed, such as occur in many places of the mountainous parts of Derbyshire; and the same are found in other like countries of the world, however remote from one another. Though I impute the formation of subterraneous rocky caverns to a ruin or fall of the loose rock underneath; yet it must be allowed that many of these passages, which in the North are called *swallows or swallow-holes* *, are the remains of those openings, by which the waters of the flood found their way to the lower parts of the earth. Many of them have

* Vast numbers of these swallows are to be seen at the *Cross-fell* mountain of Cumberland, and about *Ingleborough* mountain in the West Riding of Yorkshire, some of unfathomable depths. A large account of many such in all parts of the world, is to be seen in Mr. Catcot's Treatise on the Deluge, p. 355. &c. second edition.

a direct perpendicular descent, like the hollow of a well; as that of *Elden-hole* in Derbyshire. Without question, some of these may lead at this day even quite down to the grand reservoir of water beneath the earth; and if we suppose such unfathomable apertures under the waters of the ocean, in open seas and deep bays or gulphs, they will give a more easy solution of the under-currents of the ocean, and some other strange and curious phænomena, such as that of the *Mael-stroom*, or vast whirlpool of the northern sea, and many like in-draughts in other parts of the globe, than any other principle in nature.

While we are considering the accidents that have happened to the terrestrial strata, we ought not to pass over one which is very observable; and some learned authors of credit have asserted it so positively, that I suppose it to be a fact, though I am not able to affirm it upon my own observation. It is this: that the broken sides of high mountains, where they are most abrupt and abounding with craggs and precipices, are generally found to the westward. Hence it is inferred, that the tides and currents of the diluvian waters in this hemisphere tended that way; carrying before them the looser parts of rocks and

and mountains, which would fall away and break off more abruptly in that direction. And for this there might be two reasons: first, that when the solid parts were formed and compacted underneath, the waters that flowed above, being of a looser texture, would be left behind, as the diurnal rotation carried the earth forward with its due velocity; and secondly, that this motion would be aided and increased by the apparent diurnal motion of the sun and moon from east to west, for the same reason as the tides are generated in the ocean. It may be worth the trouble to any curious observer, to bear this in mind, and examine, when his researches are favoured by proper opportunities, how far the fact here mentioned does really obtain in nature.

Case of Caldy Island.

We cannot, by digging into the earth, obtain a view of the position and nature of the strata for more than some few hundreds of yards; but there is one curious instance of an island near the coast of Pembrokeshire, where the earth suffered the accident of so unusual a disruption, that the strata of which the whole island is composed are placed in a vertical

position, so that their edges are all exposed to view, and they may be observed in succession from one side of the island to the other. Here then we have the singular opportunity of seeing in what order they were originally placed to the depth of two miles. At one end of the island they are not more than a foot thick, but increase as we proceed, till they terminate in a stratum of red stone more than a mile in thickness; which, with good reason, is supposed to have been the lowest of them all before they were elevated and thrown upon their edges. The thinner strata, which were originally uppermost, have fossil shells and corallines in them; but I have not heard that any thing like the traces of lava are to be found, to countenance the supposition that this strange accident was occasioned by the explosive force of a volcano.

It would be endless to recount the many smaller accidents which have been observed by miners, in their researches after minerals and metals, their various mixtures, positions, ramifications, and other diversities, from which they have formed rules to direct them in their inquiries; but which, after all that can be learned, are scarcely reducible to any certain science. These things being out of our

our province, we leave them to consider some other particulars relating to the internal œconomy of the earth; the chief of which are, first, the resources of water for the common supply of springs; secondly, volcanos; thirdly, earthquakes.

IV. On the Origin of Springs.

Many and various are the theories which have been invented to account for the phænomena of springs and rivers; but they are all reducible to two: some say, that the cause is above the earth; others, below it: the former maintaining, that the rains which fall upon the earth are sufficient to account for all the phænomena of springs; the latter, that they are chiefly derived from the vapours, veins, and issues of the great abyss, into which they are all returned; and that a perpetual circulation and equality is kept up; the springs never failing, and the sea, by reason of its communication with the subterraneous waters, never overflowing. We are briefly to examine the merits of these two different accounts.

Springs not from Rain and Vapours only.

That the rain and vapour which fall upon the earth cannot account for the origin of

springs and rivers, will be evident from the following considerations : first, that the rivers of a country have been compared with the rains that fall annually upon it, and have been found to exceed the rain in quantity. Some learned philosophers of Italy found, by a calculation which seems to be so fair that it makes more allowances than are reasonable, that the waters, discharged into the sea by the rivers of Italy, are to the rain which falls upon the land as *55* to *27*; that is, more than as much again *. Secondly, that the earth is constantly moistened to a greater depth than the rain of the year will account for. Thirdly, that the consumption of moisture by vegetables and the fruits of the earth is much greater than has been commonly supposed and allowed for; so great that all the rain that falls is not sufficient to supply them with what their growth demands. Dr. Hales found, that a plant in twenty-one days and one quarter draws off all the water of the earth on which it grows; so that without a farther supply from beneath, it

* See Mr. Catcot's Treatise on the Deluge, p. 174, &c. of the second edition: where the learned author has given us the most critical and satisfactory discourse extant, on the origin of springs and rivers.

it must perish after that time; and yet he has made no allowance for what the portion of earth in question perspired at the same time by its own pores in vapour. Fourthly, that there are springs, and those every-where common, so equal and constant in yielding their waters at all seasons, and which are affected neither by rains nor droughts, that we cannot suppose them to depend on any such causes. Mr. Derham describes one such under his own inspection, which was by no means consistent with the hypothesis of rain and vapour. Fifthly, that there are springs too near the summit of the highest grounds in the country, to derive themselves by descent from the water which falls on the surface of the ground; there being no declivity sufficient to account for them in this way.

Sixthly, that the evaporation of the sea, which has been called in for this purpose, and supposed to have furnished vapours, which being condensed by the tops of high mountains, soak in there, and produce springs and rivers, is by no means sufficient to account for them. For, whatever effects this vapour may seem to have in southern climates, and in islands placed in the middle of the ocean, it cannot be fairly applied to the springs

springs of inland countries and northern climates: nor has it been considered, that, where the evaporation of the day is so copious, the dews of the night, which fall again on the same surface, are so nearly in proportion that much less is gained this way than has been supposed. Besides, it is notorious, and Dr. Derham judiciously insists upon it in answer to the doctrine of evaporation, that springs occur in great plenty, and are constant in their course even in times of the greatest drought, where the country in general is low, and there are no mountain tops to condense the vapours. What can we do in such cases, but have recourse to some other supply?

It would be absurd to deny that rain and melted snows produce many temporary springs, and increase the discharge of rivers; because we see it with our eyes: but this is a partial consideration, by no means adequate to that constant supply, and to that vast quantity of waters which are to be accounted for; therefore let us try what the other solution will do, for the calculation of the subterraneous stores, and the vapours that arise from them.

Sources

Sources of Water lie very deep.

And here it is a well known fact, that we never fail to find waters when we penetrate deep enough into the bowels of the earth; and the deeper we go, the waters occur in greater plenty. This does not look as if their stores depended upon any accidents at the surface; for then they would rather be diminished, and fail us when we work lower, their supplies being extended in springs and rivers upon the surface: but the contrary is always the case; therefore the sources are not above, but below. The conclusion appears too obvious to be avoided. In sinking mines, it is very common for the workmen to break in upon veins, and sometimes large and powerful courses of water in incredible quantities, which overflow the works past remedy, or require the continual assistance of engines to drain them off. When the earth is cut through, it yields water, as naturally as the body, which abounds with vessels, yields blood when it is wounded. The deeper the wound, the greater is the effusion of blood, because the largest channels lie deep; and the largest of all, which feed the rest, are placed in the central parts of the body. Thus it is with the body of the

the earth: the effusions observable near the surface have their supply from reservoirs which lie deeper, and they in their turns are fed by larger and deeper, till we come to the grand repository of all, which keeps up a general communication between the waters of the land and those of the sea*.

The learned Dr. Hales objected to all supplies from an interior *abyss*, because the surface of it in the seas at high water are lower than the land. But, in answer to this difficulty,

* The Greeks are supposed to have allowed this doctrine concerning the origin of fountains from the sea, by giving to their Neptune the name of Ποσειδων, *giver of drink*; for this is not true of the sea, but so far as it ministers water to the springs of the earth; for salt water is not fit to be drank. In their mythology, Pegasus was the son of Neptune, and was so called from Πηγη *a fountain*, to signify that fountains are born of the sea.—Ποσειδωνος υιον ειναι τον πηγασον, απο των πηγων ωνομασμενον. *Phurn. de Nept.* As rivers are supplied by springs, then if rivers are said to come from the sea, it is implied that springs do so too. This is the doctrine of the Scripture: *all the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again.* Eccl. 1. This is the true reason why the sea never exceeds its bounds, though it receives all the rivers of the world, because the rivers themselves derive their origin from the sea. What it receives now, it gave before; and what it is now giving, it will receive again; so that its waters neither fail nor overflow, because there is a perpetual circulation.

culty, we are to remember, that the waters of the sea are salt, while the spring waters of the land are fresh, and consequently lighter; so that a column of sea-water will be a counterpoise to an higher column of fresh water. If, therefore, the water of deep seas has any communication with the land, and their weight has its due effect, water may rise to any height required, upon the principles of statics; either by running channels, or by sap and percolation; in which case, the effect will be forwarded by what we call *attraction;* for a mass of dry sand, with water underneath, will be soaked upwards to its surface. Sir Isaac Newton tried this experiment on a tube filled with dry ashes, and found that the water ascended through them with ease. In the rocky caverns of mountains, much may be done by the slow ascent of steam, which will be condensed as it comes near to the air, and distil downwards again through those cracks and chasms where it finds an outlet. When they dig for springs in small islands and lands lying near to the sea coast, it is common to find veins of brackish water: these certainly are derived from the sea. The water that is found more remote, and at a greater elevation, becomes fresh

fresh by degrees; therefore it sweetens in its progress by percolation. Here the process is palpable. Now let us only carry this forward, and the difficulty is over: for it can scarcely be denied, that the earth, so full of open veins and fissures, and moreover with strata of loose and permeable matter, must have communication with the sea to very great distances: and where the distance is so great, that the lateral supply cannot be supposed to take place, those deeper communications, of which we have so many evidences, will never fail us; and where percolation cannot reach, the subterraneous vapours, which are always circulating, must have their effect.

Some moderns are unwilling to allow that there is any such thing as motion, in consequence of heat within the earth; but they who have been eye-witnesses of what passes within the earth are generally of opinion, that steam and vapour is stirring there at all times, though at some more than others; that there is frequently a very sensible warmth at the greatest depths, and many tokens of moisture rising upwards from the lower parts; and that hot springs are undeniable proofs of internal heat: Scheuchzer, who was

was very conversant in these researches, declares his sentiments in the following words: *Firmiter persuasus sum, copiosissimos ex imis montis visceribus ad cacumen sublevari caloris subterranei ope vapores aqueos.* If this vapour is admitted, and we add it to the other helps that are afforded us, there can be little difficulty in the theory of springs and rivers. The very moisture with which the earth is at all times saturated at great depths, is of itself a demonstration, when compared with experiment, that the supply is from beneath. Mr. De la Hire found that the rain of fifteen years conveyed not one drop of water to the depth of eight feet, through loose and permeable earth that was properly exposed to it, and had a drain made at the bottom to discharge the water, if any had been collected. The inland parts of countries most remote from the sea, do generally abound with hills; and there it may very reasonably be allowed, that the rains which fall in greater plenty, and the vapours which settle upon the more elevated parts of the earth, come in for their share.

V. On Volcanos and Earthquakes.

From the waters of the earth, we proceed to consider the effects of fire in volcanos and earthquakes; which will bring us near to the conclusion of this discourse.

The body of the earth has many strange outlets or *spiracula*, which, like ulcers in the human frame, discharge peccant humours; and which, terrible as they may seem, serve to prevent more dreadful and destructive effects in the constitution of the globe. Such are Etna in Italy, which has raged at intervals from time immemorial; for we have no history of its first appearance. The same may be said of Vesuvius in the kingdom of Naples, Hecla in Iceland, and perhaps of others in the mountains of the southern continent of America: we hear of none in the northern. We must first consider the causes of these, then the effects, and lastly, make some inferences from them.

Volcano represented artificially.

The chemists have a method of making an artificial volcano by mixing iron filings with sulphur, and making them damp with water,

so that they may be wrought up together into a paste. If these ingredients are compounded in any large quantity, and confined either in a vessel of earth or under the ground, they will heat and ferment, and at last take fire and burst out with an explosive force. Observation shews us that those are the ingredients which in the subterraneous regions work together, and furnish that matter which is cast from the mouth of the volcano, or at least which occasion that raging explosive force by which the contents of a volcano are discharged. The melted matter, called *lava*, is a composition of minerals, metals, and sulphur; and, from their effects, it is certain they are lodged at a vast depth in the bowels of the earth. The fossil called pyrites is a mineral composed of iron and sulphur; immense quantities of which are found in some parts of the earth: when these ferment with the steams of water which are perpetually rising from beneath, they send forth an inflammable vapour, which is attended with noxious and destructive effects in mines, and is called a *fire-damp*, or fulminating damp. It is often perceived, in the coal mines of this kingdom, issuing as a lambent flame from cracks and fissures; but it rarely

takes fire till it comes into contact with the flame of a candle. Mere ignition, or red-hot fire, without flame, has no effect upon it; for which reason the labourers in mines do, in some places where the danger is very great, work by light from flint and steel, instead of using torches or candles. The accounts which are given of these damps are very surprising. In coal works they are sometimes seen in the cavities of the pit, shining like kindled sulphur; sometimes flashing and darting from one side to the other; and being kindled into actual flame by a candle, they go off with a blast or explosion more shrill than the noise of a cannon, tearing the clothes of the workmen to pieces, singeing their bodies, forcing away the frames and engines and carrying them aloft into the air. Sometimes these damps rise up, and hang about the roof of a pit, from whence they extend themselves into contact with the light of a candle, as if they were moved by some instinct. We are not able to affirm, on any authority, whether these damps were ever known to take fire of themselves: the reasons of which may be, that the fermentation and commotion underneath is too weak; that the materials are not pro-

perly

perly mixt for this purpose; that something is wanting, or perhaps an acid is too redundant, so that the vapour is not of the proper kind to take fire, till it comes into contact with some phlogiston. It must be supposed that the case is different with volcanos; that the cause of their accension is within themselves; and that when once kindled, they never totally expire to the end of the world, unless the materials fail, and there is no more fuel to feed them.

Materials of a Volcano.

If we examine what these materials are which co-operate in the combustion of a burning mountain, we shall discover bituminous earths and stones, sulphur, nitre, iron, and other metals, with fire to put them in action, and water to increase the effects of it. The fixt alcaline salt, which is a production of fire from some other neutral body, and is found near the mouths of volcanos, makes it probable that a nitrous salt is among the other ingredients of a volcano; for nitre, when deflagrated, turns into a fixt alcaline salt: that sulphur has a great share, is indisputable, from the vast quantities of it that are thrown from Etna and Vesuvius; and its

appearance shews that an alcaline salt is mixt with it; for it looks red and rusty, as when brimstone and salt of tartar are melted together, according to the process in Boerhaave's Chemistry*. I have some crusts of sulphur, almost pure and simple, which were taken liquid from the mouth of Etna by a bold English sailor, who descended so far into the crater, that he dipped his oak stick into the melted matter, and satisfied his curiosity without paying for it as Pliny did of old.

Thus it appears, that nature itself exhibits to us a sort of subterraneous gunpowder, which has its share in the production of a volcano. But there is another agent much more powerful than gunpowder. When a metal is in the heat of fusion, if the smallest quantity of water comes into contact with it, an explosion follows, and the parts of the metal are scattered abroad in all directions, and in some cases totally dissipated. This effect happens in melted lead; but is most remarkable in copper and brass; which, if they are melted in a large quantity, and water comes to them by accident, or the mould is damp, the explosion is like thunder; and the force is equal to the noise; for the mass is

* Practice of Chemistry, Process CLII.

is scattered by the blast, as dust is blown away before the wind: such is the force of water, suddenly converted into steam by a violent heat, and spreading itself amongst the parts of a metal in fusion. How far water is capable of dilatation when turned so forcibly into vapour, we are not able to compute. Here we have two different forces, that of sulphur mixt with nitre, and that of water converted into vapour by red-hot metal, which are sufficient to account for all the phænomena.

If the imagination could penetrate to the hidden recesses of a burning mountain, and become acquainted with what happens there, how tremendous would be the scene! We should find caverns, or rather cauldrons, of a mile in extent, perhaps of several miles, with a fiery mass larger than a living eye could comprehend, rolling furiously about, with flashings of fire brighter than the sun, and bellowings louder than thunders. We should see the earth undermined by the flames, and breaking in upon the fire with fresh stores of combustible matter, and veins of water pouring in at the same time upon the burning mass, the blasts of which, when repelled by such an immense fire, drives be-

fore it stones, cinders and ashes, and carries them aloft into the air. When a volcano is viewed in the night, we may discover, by the colours that appear, what ingredients prevail in the fire. If the smoke is very black and pitchy, we may conjecture that the fuel has coal and bitumen in it: if the smoke is whitish, it is mixed with copious steams of water; if the fire is white and bright, the fuel is nitrous; if livid, sulphureous; if red, it consists chiefly of melted metals and inflammable earth.

Effects of Volcanic Matter.

The visible effects of this dreadful composition have been described at large by many ancient and modern writers, who have given us accounts of the eruptions of Etna and Vesuvius; and, latest of all, by Sir W. Hamilton, who was present at the great eruption of Vesuvius in 1766, and is very particular in his observations. We owe to him a complete collection of specimens of all the kinds of matter which are found in the neighbourhood of Vesuvius, with which he has enriched the British Museum.

A writer in the year 1717 has given so lively a description of the symptoms in an eruption

eruption of Vesuvius, that I shall here extract some parts of it, as being concise and proper for our purpose, to give the reader an idea of a volcano. "I reached the top of "Vesuvius, in which I saw a vast aperture "full of smoke, which hindered my seeing "its depth and figure. I heard certain "strange sounds within, which seemed to "proceed from the belly of the mountain; "a sort of murmuring, sighing, throbbing, "churning, dashing as it were of waves, and "between whiles a noise like that of thunder "or cannon, which was constantly attended "with a clattering, like that of tiles falling "from the tops of houses into the street. "When the smoke was driven aside by the "wind, we saw two furnaces, glowing with "red flames, and throwing up red-hot stones "with a hideous noise, which as they fell "back caused the afore-mentioned clatterings. During the progress of this eruption, when the smoke went upright, we "could see that the crater was a mile in circumference, and an hundred yards deep. "I could discern one of the furnaces to be "filled with a red-hot liquid matter, like that "in a glass-house, which raged and wrought "as the waves of the sea, causing a short

"abrupt

"abrupt noise, like what may be imagined "to proceed from a sea of quicksilver dash- "ing among uneven rocks: while another "aperture sent up clouds of smoke. When "the mountain raged, and the fits were most "violent, you cannot form a better idea of "its noise, than by imagining a sound com- "posed of the raging of a tempest, the mur- "mur of a troubled sea, and the roaring of "thunder and artillery, confused all toge- "ther: and this noise we heard at the "distance of more than twelve miles. Some "of us got into a boat, and were set on "shore at the foot of the mountain to the "south west; after which we rode four or "five miles, and came at midnight to the "burning river that flowed from the crater. "The mountain grew exceeding loud and "horrible: in the cloud over the crater va- "rious colours were seen, of green, yellow, "red, and blue; there was likewise a ruddy "dismal light in the air, over that tract of "land where the burning river flowed. "Ashes were showered upon us all the way "from the sea-coast: which circumstances, "set off and augmented by the horror and "silence of the night, made a scene the "most uncommon and astonishing I ever

"saw.

"saw. Imagine a large torrent of liquid "fire rolling from the top down the sides "of the mountain, and carrying every thing "before it; then dividing itself into chan- "nels, one of which was half a mile broad "and five miles long. A gentleman, whose "window looked towards Vesuvius, assured "me, that on the last night of the eruption "he observed several flashes, as it were of "lightning, issue out of the mouth of the "volcano*." This latter circumstance was particularly noted by Sir W. Hamilton, that actual thunder and lightning, with all their usual effects, were produced from the clouds of smoke and ashes over Vesuvius; and indeed the like has been noted before by other authors, from Pliny junior to the present age. Sign. Jos. Valletta writes thus of it in the Phil. Trans.—*Cæterum inter plurima montis effervescentis phænomena, duo certe fuere a multa ætate non visa et ignota: tertio namque die aut quarto, fulgetra emittere ex orificio cæpit, ejusdem fere aspectus ac quæ e cælo interdum mi care videmus, sed tortuosa et serpentia; et in eorum emissione tonitruorum bombi audiebantur. Fuere ea tam spissa et*

* Phil. Trans. N° 354. p. 708, or Abridg. Vol. V. p. 233.

*et frequentia, ut primo quidem putaremus pluviam casuram; usq. quo animadversum est, obscuras nubes non ex vaporum materiâ, sed densitate cineris cadentis compactas**. In one of the eruptions of Vesuvius, its ashes are reported to have been spread over all Europe, and carried as far as Constantinople. The rivers of melted matter, or lava, have been known to run above twenty miles from the top of Etna, and advance a considerable way into the sea.

Burning Mountains have Consent at great Distances.

It is a circumstance not less extraordinary than any of the foregoing, that burning mountains have been observed to keep time with one another in very remote parts of the world. Mr. Ray relates from Gassendus, in his Life of Peiresk, that there happened an eruption at the mountain Semo in Ethiopia, at the same time with that of Vesuvius, in 1633. The like had been reported of Etna, Vesuvius, and Stromboli; but in them, which are so much nearer together, it is not so remarkable that they should act in concert; whereas Semo in Ethiopia is near 20 degrees

* Phil. Trans. N° 337, p. 22.

degrees of a great circle, that is, about two thousand miles from Vesuvius; which is so large a tract of the earth's superficies, that though we may possibly imagine the European volcanos to have communication by subterraneous canals, nothing can well account for such distant commotions, but a cause more extensive, such as that of a vast abyss of water, by which the whole earth is undermined. Pliny delivers it from authors more ancient than himself, that it is the nature of some subterraneous fires to be kindled by the access of water: *flagrat in Phaselide mons Chimæra, et quidem immortali diebus et noctibus flammâ. Ignem ejus accendi aquâ, extingui vero terrâ Ctesias tradit.* Lib. II. C. 106.

Volcanos cast out Water.

But it is still more to the purpose, that, on some occasions, these mountains, which seem to us to act in their proper character only when they throw out fire, are known to pour forth from the same orifices vast floods of water. In the year 1682, when there was a vast inundation in Sicily, from a storm of rain which lasted six and thirty hours without intermission, Mount Etna at the same time

time cast out such abundance of water, that all the neighbouring country was drowned *. This unexpected relation between the subterraneous waters and the subterraneous fires is farther confirmed by this undoubted fact, which has often been taken notice of, that the most violent eruptions of Etna and Vesuvius are generally attended or succeeded by a course of rainy weather. If they were preceded and ushered in by wet weather, it might be supposed that their fires were excited by the rain from above; but the fact shews, that the water which affects them is all from beneath. The same inference is to be made from the phænomena of earthquakes, which are nearly related to those of volcanos, and proceed mostly from the same causes, insomuch that at a volcano we may suppose an earthquake to have its vent; while, on the other hand, an earthquake may be looked upon as a stifled volcano; the cause of which lying too deep to overcome the immense weight of the incumbent earth, is therefore the more extensive in its effect, and agitates vast tracts of the earth at once. Some earthquakes have been so extensive, that it would be impossible to account for them, but by supposing

* Mr. Ray's Three Disc. p. 286.

supposing some cause to be concerned that is capable of shaking the whole earth at once; as if that invisible philosophical monster, the internal nucleus of the globe, was moved and shifted in its watery bed.

The heathen mythologists, according to their constant practice of forging miraculous fables out of the plain history of nature and natural causes, transformed volcanos into persons, and added an history of their actions. They described them under the character of monstrous giants, such as Briareus and Typhon, sons of Neptune and Tartarus, who rebelled against Jupiter, and are now struggling in the bottom of Etna; all of which means nothing more, than that burning mountains breathe out fire and vapour into the sky, and imitate the thunder and lightning of the upper region; encroaching, as it were, upon the province of Jupiter, who sends his lightning downwards from heaven, to prevail against that which they send upwards from the bowels of the earth. As Jupiter is said to have conquered them, and imprisoned both Briareus and Typhon in the depths of Etna, this last circumstance is a key to the physical interpretation of all the fables relating to the giants, and their ex-

ploits in opposition to Jupiter. Briareus is also called by the name of Ægeon, under which he is alluded to and described by Virgil:

> Ægæon qualis, centum cui brachia dicunt
> Centenasque manus; quinquaginta oribus ignem
> Pectoribusque arsisse; Jovis cum fulmina contra
> Tot paribus streperet clypeis, tot stringeret enses.
>
> Æn. X. 565, &c.

Phurnutus, in his Physical History of the Gods, supposes the hundred hands of Briareus to denote the powerful effects of terrestrial exhalation *, which is consistent with the other interpretation, because the eruption of a volcano is only the most violent of all terrestrial vapours.

Of Earthquakes.

There is so near a relation between burning mountains and earthquakes, that they may be understood as different effects of the same causes, acting according to circumstances. The eruption of a volcano is generally attended with an earthquake, which either precedes the eruption, or is contemporary with it; so that a volcano is an earthquake

* Διανεμονται πανταχοθεν αι εκ της γης αναθυμιασεις, ως δια πολλων χειρων. p. 37.

quake venting itself by an eruption, and an earthquake is a subterraneous blast which has no regular vent at the surface. The shaking which attends a visible eruption, seldom extends far from the place; whereas there have been earthquakes which have extended to very large tracts of the globe. In the reign of Valentinian there was an earthquake, by which the whole known world was shaken, and probably the unknown also. On the first of November 1755, when the memorable earthquake happened at Lisbon, the seas, and lakes, and ponds, and rivers were affected all over Europe; and strange explosions were heard by the workmen in some of the mines of Derbyshire. In some cases the fire which occasions an earthquake may be culinary; in others it may be a vaporous blast; and in others there may be a translation of the fire, which we call electrical; which, from some late observations, seems to take place in the subterraneous regions of the earth. There may be instances in which all these causes concur together.

That actual fire is always concerned as the cause of earthquakes, is not certain, though the great force of them seems to indicate the agency of fire in some shape or other; some-

 times,

times, perhaps, so remote, that the immediate signs of it do not appear to us in the disruptions which take place at the surface. Some learned writers have thought, that such earthquakes as have no communication with any volcano, are yet to be ascribed to the kindling and explosion of some fire-damps, and that it is not necessary there should be any actual appearance of fire on such occasions; because it may be dissipated in the caverns of the earth at a great depth before the shock is felt, as the fire of lightning is gone before the noise of thunder is heard. But this solution will agree best with such earthquakes as have but one single pulse. And it is deficient upon another account; for a fire-damp or mineral explosion is a dry cause, whereas the phænomena of earthquakes are frequently such as demand some cause in which water is eminently concerned. Such a cause also is required as may be adequate to the most extensive effects, and be present to all places at once; and I suppose no other can be assigned, but an immense body of water under the earth, which, communicating with the sea, and co-operating under different circumstances with that subterraneous fire, which may be called the vital heat of

of the terraqueous globe, produces all those agitations which we call earthquakes.

Earthquake analogous to the Horror which precedes a Fever.

There is undoubtedly a *perspiration* from the earth, which, when regular, passes off like insensible perspiration in an healthy body; but when obstructed, or increased to a violent degree, produces effects similar to those of a febrile heat in the body, and a concussion ensues, which commonly is succeeded by a vast effusion of watery vapours and great falls of rain, analogous to the profuse sweats which break out from the human body after a shaking fit. I do not appeal to this analogy as if it were an argument; but there is a certain uniformity in the several parts of nature, which will give us light, and keep us within the bounds of truth, and is therefore always worth attending to. That earthquakes do really proceed from an obstructed perspiration in the body of the earth, is confirmed by these two observations: first, that they are commonly preceded by a great drought, and a series of fine weather; and secondly, that they are succeeded by great rains. When an earthquake is at hand, all

things seem to be quiet, and there is no prospect of danger to alarm us, which is a matter rather of moral than philosophical consideration; from which it will be inferred, that earthquakes are intended for judgments, and do therefore take the world by surprise. This was the case when the great earthquake happened at Port-Royal in Jamaica. "It "is very remarkable," says Mr. Ray *, "that the day when all this befel Port-Royal, "and the whole Island of Jamaica, was "very clear, not affording the least suspi-"cion of evil, so that the inhabitants had "no warning at all of it, but were surprised "of a sudden without time sufficient to "escape and save themselves." I remember well, that, on the other like occasion, of the great earthquake at Lisbon, every body was struck with that awful circumstance of its sudden approach when the day was calm and bright; the fate of Sodom naturally occurred as a parallel—that city, in which *the sun was risen* as usual, when the moment of its destruction was at hand. All accounts agree in this circumstance likewise, that earthquakes are succeeded by incessant rains: that of Lisbon certainly was; the seasons which followed

* Three Discourses, p. 268.

lowed being the most rainy I ever remember, and they continued so for some years afterwards. Vesuvius is known to rage most in bad weather, and to emit a white turbid smoke, which shews that much watery vapour is at such times intermixed with it.

The barometer has been observed to fall unusually low at the time of an earthquake: I never saw it but once at the bottom of the scale, at 28 inches; there was no rain here at the time, but a great flood soon afterwards: and I was informed that the same sinking of the barometer was observed in Switzerland, and that they had an earthquake there on the very day. All these things, and many other particulars that might be enumerated, conspire to shew, that volcanos, earthquakes, and great rains, and other phænomena of the atmosphere, are affected by a subterraneous fund of steam and vapour; with which other causes may co-operate, such as subterraneous fires, condensed air generated from heterogeneous mixtures, &c. which it would be difficult to ascertain and adjust: but this subterraneous fund seems to be the main spring which animates and gives motion to all the rest.

It was an opinion of the ancients, which

I have met with in Seneca's* *Natural Questions*, that some earthquakes are owing to subterraneous winds; and some late observations

* In the sixth book of Seneca's Natural Questions, the reader will find collected together an epitome of all the learning of the ancients relating to the causes of earthquakes; which are reducible to these three, water, fire, and air. Thales, who held the Mosaic doctrine, that the earth is founded upon the waters, supposed that nothing more was necessary to produce earthquakes, than some irregular agitation of the waters that are under the earth. Others accounted for them from fire, or from the co-operation of fire and water; having observed that nothing can resist the force of boiling water, when turned into vapour by fire. *Cum pluribus locis ferveant (ignes) necesse est ingentem vaporem sine exitu volvant. Videmus aquam spumare igne subjecto: quod multo magis illum facere credamus, cum violentus ac vastus ingentes aquas excitat: tunc ille, vaporatione inundantium aquarum, quicquid pulsaverit agitat.* But he adds, that the best and greatest authors all agree to derive earthquakes from the motion of subterraneous air; which, occasionally becoming more and more condensed, must force a vent, if it meets with any obstruction. He confirms this from the observation so frequently made, that an unusual calmness and stagnation of the superior air precedes an earthquake, indicating that there is some obstruction below—— *quia vis spiritûs, quæ concitare ventos solet, in infernâ sede detinetur.*

Then he gives the sentiments of Aristotle and Theophrastus, that there is a constant evaporation from the earth upwards, which, if it has no vent, returns upon itself, and is condensed,

tions argue that they have their share in these effects. The waters of the earth yield wind continually; and such a vast body as the subterraneous water of the globe, when air is ge-

condensed, till it forces its way, and in so doing shakes the superior parts of the earth. He infers the presence and action of air on these occasions, from the murmurs and bellowings which have been heard at the time of earthquakes; for all voices are from the air—*antequam terra moveatur, solet mugitus audiri; ventis in abdito tumultuantibus.*

It was natural for those who believed the earth to be an animal, to illustrate the shaking of the earth by that which happens in a human body. The air, they said, is taken in from the air without: if it passes off by perspiration, &c. well; but if it mixes with the blood, and runs about the body, it raises the commotion of a shivering fit: and thus it happens when air is detained within the body of the earth. Others held, that the earth is full of cracks and caverns filled with air; into which if the waters of the sea happen to force their way, the air must be driven out with violence, and produce either a disruption or a tremor of the earth above: and that the cause is often shewn by the effect; a violent wind for many days having proceeded from the ruptures consequent to an earthquake; as we have it from many authors.

In the process of his discourse, Seneca has one very subtile argument to prove that air is the true cause of earthquakes; because in all cases when air makes an effort to break out, its first shock is always greatest, the air being then densest; and all the succeeding ones lessen by degrees as the air becomes more rarefied; as it happens in the successive explosions of

nerated from it in great quantities, may occasion vast concussions as it is making its way towards the outlets and pores of the earth.

Earth-

an air-gun. Fire does not follow this rule: its first effort is not greatest, but it rises to its height by degrees.

He that will be at the pains to read over the sixth book of Seneca, from which I have made these extracts, will find how little the moderns have to add on this subject to the doctrine of the ancients.

Aristotle insists much on the subterraneous air as a cause of earthquakes; for which he is cited at large by Stobæus, Ecl. Phys. lib. i. where several observations are to be found which later authors have copied. Pliny, speaking of earthquakes, gives the preference to air, as a probable cause of earthquakes, without excluding others——*Ventos in causâ esse non dubium reor*——*intremiscunt terræ post ventos conditos, sopito mari, cœlo tranquillo*, &c. With respect to the history of earthquakes, he has two important remarks: 1. that places bordering upon the sea are more subject to earthquakes, which is confirmed by the chief earthquakes upon record; especially those of modern times, as that at the Port of Lima in South America, Port-Royal in Jamaica, Lisbon in Portugal, &c. 2. That there is commonly a sign in the heaven by which it may be known that an earthquake is at hand. He describes it as a narrow cloud, like a black line, extended along the sky to a great length——*tenuis linea nubis in longum porrectæ spatium.* Lib. ii. cap. 81.

To this note I shall subjoin an anecdote relative to the subject of earthquakes, which shews how things very great and remarkable pass off with little observation, and are

totally

Earthquakes would probably happen much oftener than they do, if it were not for the vent that is given to subterraneous exhalations by the many fissures that are in the strata, which are the *spiracula* of the earth, like *chimneys* to clear a room of its smoke; and when they do happen, they would be more

totally lost to posterity; while many insignificant events of the same time make a great figure, and are pompously recorded in history. This appears from a memorial in the parish register of St. Peter's in Colchester. "On Thursday, "September 8, 1692, there happened, about two o'clock in "the afternoon, for the space of a minute or more, an univer- "sal earthquake all over England, France, Holland, and part "of Germany: and it was particularly attested to me by the "masons plastering the steeple of St. Peter's in this town, "and upon the uppermost scaffold, that the steeple parted so "wide in the midst, that they could have put their hands into "the crack or clift, and immediately shut up close again, with- "out any damage to the workmen (who expected all would "have fallen down) or the steeple itself. Most of the "houses here and elsewhere shook, and part of a chimney "fell down on the North Hill; and very many who were "sensible of the shock were taken with a giddiness in "their heads for some short time. In witness of what is "here related, I have hereunto set my hand,

"Robert Dickman,

"Minister of St. Peter's, Colchester.

We do not find that this fact is mentioned by any historian of the time; and yet, being inserted in this place and manner, has greater authenticity than if we had met with it in print.

more fatal, if it were not for these cracks, which give room for the earth to bend and yield without breaking: this it could not do, if it were solid and continuous in all its parts. Some degree of elasticity, however, must be allowed to the solid matter of the earth, because it is observed, that steeples and buildings of stone will yield without parting; as the ingenious Mr. Mitchell has noted in his Treatise upon Earthquakes. Some have endeavoured to account for the elevation of mountains, and the irregular form of the earth's surface, from the force of earthquakes and explosions from beneath bearing up the surface, and disposing it into mountains, rocks, and precipices; but they should consider that pertinent observation of Mr. Ray, that "earthquakes and eruptions of volca-"nos are causes which operate to the *lower-"ing* of mountains, levelling of the earth, "straitning and landing up of the sea, com-"pelling the waters to return upon the dry "land." Though some mountains, improperly so called, which are indeed little more than heaps of cinders and pumice stones, have been owing to fiery eruptions, the assertion of Mr. Ray is true, that the earth is rather depressed than elevated by forces from beneath.

We

We have been witnesses, in these latter times, to three dreadful accidents of this sort; and it has not appeared in any one instance that any rocks and mountains have been raised, but that such as were before have been fractured and lessened; that many elevated parts have subsided, and the sea has broken in and taken place of the land which had sunk.

To what has been said of earthquakes, I shall here add an account of a subterraneous explosion, which happens from a very obscure cause in a sort of fossil called the *Slickensides*, of which I saw a specimen in Sir A. Lever's museum: this stone has the appearance of black marble, and breaks, where the explosion happens, with a polished surface, not truly plain, but lying in waves. It is found in fissures of lime-stone, in Haycliff and Ladywash mines at Eyam, and in Oden at Castleton in Derbyshire. It is divided into two equal parts, or slabs, by a line parallel to the sides of the fissure; and these slabs are joined by two polished faces, which seem to be in perfect contact, without any cohesion. The surfaces are coloured with lead ore, but as thin as a covering from a black lead pencil. If a sharp-pointed tool, which the workmen call a pick, is drawn over the vein

vein with some force, the minerals begin to crackle, like sulphur excited to electricity; in a few minutes after which, they explode with violence, and fly out as if they had been blasted with gunpowder, insomuch that the weight of forty tons hath been blown out together. These dangerous effects deterred the workmen from proceeding for several years; but at length it occurred to them that this power might be used for the carrying on of their works with better advantage than by the common method of blasting with gunpowder. Accordingly a workman makes a scratch with his tool upon the joint of the slickensides, and runs away as fast as he can to escape the explosion, which perhaps loosens as much of the rock as ten men would have brought away in three months by the ordinary methods.—I borrow these particulars from some late *Observations* by Mr. Whitehurst on the *Strata* in Derbyshire, p. 185, &c. who adds, that, in the mines where this phænomenon occurs, the workmen were much alarmed on the first of November 1755, about ten o'clock in the morning, the time of the earthquake so fatal to Lisbon. The rocks which surrounded them were so much disturbed, that soil, &c. fell from their joints

or

or fissures, and they heard violent explosions as of cannon, for fear of which they fled to the surface, and, when all was quiet, were surprised to find, on examination, that nothing material had happened under ground. It is probable the shock of the earthquake had disturbed some of the slickenside-mineral far under ground, and occasioned it to part and explode.

When vast effects arise from a cause which seems to be inadequate, it is now the custom to refer them to that class which is called electrical. Whether this effect may be deduced from the electric medium, time and farther observation must discover: in the mean while we may conclude, that wherever an effect seems far superior to its cause, the element of fire is concerned in some shape or other; as in the case of the spark setting an whole city into a blaze—a fact very sensibly commented upon by the late Cadwallader Colden, Esq. as it was observed before in the note at page 69.

VI. On the Changes which have happened to the Earth.

The earth has undergone many changes

 from

from the creation to the present time, from different causes. The greatest of these was its dissolution by water at the flood, which left its surface with the same general appearance it has at present.

The condition of the land has been much altered in some places by the retention of spring-water in a stagnant state; and thus what they call *mosses* have been generated in the Northern and some of the Southern counties of England. Camden gives this true and natural account of them, page 611: "*Cum terra neglecta jaceret, et rivulorum* "*procursus in patentibus vallibus non de-* "*duceretur, meatusque vel incuria vel vasti-* "*tate intercluderentur, quicquid humilius* "*erat, in hujusmodi uliginosos tractus* (mos- "ses *vocamus) vel stagna fuisse conversum.* "*Quod verum si sit, non est cur mireműr* "*tot arbores hujusmodi locis passim per Ang-* "*liam, sed præcipue hoc in agro* (Lancashire) "*obrutas et quasi sepultas jacere: cum enim* "*nimia uligine radices solverentur, ut de-* "*ciderent, et tam molli solo haurirentur et* "*immergerentur necesse est.*" It is scarcely to be denied that some mosses may have been thus generated; indeed I have no doubt of it, from what I have seen in other parts

parts of England; but some must be derived from the subsidence after the flood. So Camden thinks, and therefore he says—*Curiosa philosophorum natio hæc plenius indagabit.*

The land and water have sometimes changed places: the washing of the sea in tracts of time has carried away land from the coast, so that the sea now comes much forwarder into the country than formerly: while, in other places, the rivers from the inland parts have brought down fresh soil, which has occasioned the land to gain upon the sea. In many harbours, according to the winds and currents they are exposed to, and the kind of soil at the bottom, banks of beach and ouze have been thrown up by degrees, which have kept out the sea, and altered the form of the coast. Where the project has been favoured by the working of the sea, large flats have been gained for cultivation, and secured by imbanking from the return of the waters. Much of this work has been accomplished on the flats of Lincolnshire; and the fertile level of Romney-Marsh in Kent, as we have already observed, has the like appearance, as if it had been wholly re-

covered

covered from the sea, by a little art co-operating with a favourable accumulation of the beach in certain places: but the fact of its recovery is of great antiquity.

Mr. Gosling of Canterbury, in his late History, speaking of Stutfall Castle, near the Portus Lemanus, tells us it contained ten acres of ground, and once stood so near to the sea that ships might be moored to iron-rings long remaining in the wall there. But now the sea hardly comes within a mile and half of it, having left more than forty thousand acres of land below the range of hills it once washed the foot of; and to this we owe Romney and Walland Marshes, famous for fine mutton and excellent wool. See p. 16. of the 2d. edit. If this were so, then Romney-Marsh must have been recovered since the time of the Romans in Britain. It is certain there is great alteration since Julius Cæsar described the landing-place at Dover. He says the hills were so near *on each side* the harbour, that a dart might be cast upon those who attempted to land. This is not the case now. The soil washed down from the hills, and the beach thrown up by the sea, has so stopped the mouth of this valley,

that

that the sea is much farther off, and the back-water of the harbour seems to have acquired a different course.

It is remarked by historians, that several mountains are not so high as formerly : and this may justly be imputed to a *deterration*, which is the natural consequence of the rain descending from their tops and carrying away the soil by slow degrees. A person whom I knew well, and who lived to a good old age, affirmed, that, within his own memory, a tower was become visible from a certain point over the top of an intermediate hill, by which it had been entirely concealed when he was a young man. The soil of that hill is composed chiefly of clay and sand, both of which are subject to be washed away apace by the falling of impetuous rains. Other changes have been brought on in various parts by the breaking out of burning mountains, now exhausted and extinct, but discoverable by their remains, which plainly exhibit the productions and effects of subterraneous fires. Mountains thus formed may be distinguished not only by their contents, but by not being disposed into strata, like those of common earth or stone, as if they were disorderly heaps of rubbish.

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si ... volcanic original. Dr. Woodward had a
sort of stone sent to him from some mountains of Saxony, which was supposed to be the real production of a volcano; but having examined the specimens critically, he says of them, *quos tamen nunquam arsisse pluribus hisque certissimis documentis facile evincitur.* However,

* The reader may see a farther account of it in Mr. Whitehurst's book, p. 162, in the Appendix relating to the Strata of Derbyshire.

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he most considerable change that has pened in the natural face of the earth since the great catastrophe of the flood, is the separation of the American continent from the African and European, by the loss of a great tract of land, and the intervention of the sea; which I take to be an article of ancient history very probable in itself, and confirmed by modern experience. There was an ancient tradition in Egypt, of which Plato gives us an account in his Timæus, that a vast tract of land was swallowed up by the sea in the Atlantic Ocean, between the Straits of Gibraltar and the present coast of America; by means of which land, the American continent did once communicate much more nearly than at present with Europe and Africa:

 that

that the accident, by which this tract was lost, was no other than a violent earthquake, or a succession of earthquakes, occasioned by the eruption of subterraneous and submarine fires, which made such an alteration in that part of the globe, that the Atlantic, or western world, was from thenceforth cut off from the eastern, and remained almost totally unknown, till it was discovered again by the bold experiment of Columbus.

That such a change did actually take place, is rendered extremely probable by the ancient tradition of it, compared with modern discoveries; for the discovery of America verified Plato's tradition of an Atlantic continent; and if the tradition was not derived from some former historical knowledge, it will have the appearance of a prophecy: therefore it is most reasonable to think that there was a time when America was once better known and more easily visited.

This is farther confirmed by the present state of the intermediate islands of the Atlantic, the Canaries, Azores, &c. which appear like fragments of a shattered land, and bear the marks of volcanos and earthquakes in all parts of them; the Pico-Teneriffe itself, by the materials of which it is composed, being

being no other than an huge monument of some violent eruption. The sea, in which these islands are found, is still subject to subterraneous fires rising from its bottom, of which there have been recent instances near the island of Tercera, described in the Philosophical Transactions *.

That the eastern and western worlds were divided very early, must necessarily be supposed from the rude and ignorant state in which the Americans were found, unacquainted with the use of letters, and unskilled in the application of iron to works of art and the instruments of war. Upon the whole, it seems incredible that Plato should so exactly describe an *opposite continent* †, such as is actually now discovered, together with the way that led to it from the Straits of Gibraltar; and that this report should be grounded on no ancient knowledge of the American world, but prove to be true afterwards by accident: all this would be more

* See Transactions Abr. vol. vi. 203; compare Cluverius, lib. 6. cap. 2. In the year 1757, and in the month of July, all the Azores suffered greatly by an earthquake; eighteen new islands appeared, and considerable tracts of the old ones were swallowed up.

† Την Καλαντικου ηπειρον. Tim.

incredible than the matter reported; which, if the natural monuments of it still subsisting are taken into the account, has all the appearance of truth that can be desired: and therefore I think we may well reckon this separation of America among the natural changes which the earth has undergone since the time of the flood: and as it was brought about by a violent earthquake and volcano, the same cause might be productive of many lesser eruptions, of which we see the remains in the fossil lava which is thought to occur in the western parts of Europe *.

The last Change, from a Conflagration.

The last and greatest change which is to be expected in the earth, is that of its *conflagration*. All other past changes may be considered as preparatory to this; and therefore it ought not to be passed over in silence. Pliny, the natural historian, though an heathen in his faith, was so well persuaded of it, that he considered every burning mountain (as divines have considered the tremendous exhibition

* If the reader wishes to see any thing farther upon this curious subject, he may consult my letter in Mr. Catcott's Treatise on the Deluge, p. 152, of the 2d Edition, together with what follows at p. 160, &c.

exhibition on Mount Sinai) as an argument and earnest of the future destruction of the world by fire: "*In these,*" saith he, "*nature* "*rages, denouncing a conflagration to the* "*whole world**." The ancient philosophers, particularly the Stoics, were in possession of this doctrine, that the world had been destroyed by water, and would hereafter be destroyed by fire: the deluge was signified by the world κα|ακλυσμος; the conflagration, by εκπυρωσις and αναπυρωσις. Some learned mythologists are of opinion, that the fabulous name Pyrrha, from πυρ *fire*, was given to the wife of Deucalion, to signify that another universal dissolution was to be expected by means of fire, nearly allied to its past dissolution by water. The story of the burning of the world by Phaeton, the son of Apollo, is supposed to have been an ancient mythological representation of the same doctrine: "These things," says Plato in his Timæus, "have the form of a fable; but "the truth is this: there shall be a change "of things in heaven and earth; for all "things upon earth shall shortly undergo a "dissolution

* In his natura sævit, exustionem terris denuncians. Lib. 2. c. 106.

"dissolution by means of a great fire*." Cicero has alluded to this ancient tradition, in the philosophical discourse of his Somnium Scipionis, where he speaks of *eluviones* and *exustiones, floods* and *conflagrations*, which put a period to all earthly glory. By Ovid the flood is described almost as particularly as in the Bible itself, of which some notice hath been taken above: and the words of Lucan are as express for the conflragration. The poet, lamenting the fate of those soldiers who died in battle for their country, and were left without the proper rites of burial, elegantly introduces this consideration, that their remains would be burned at last in the common funeral of the world:

——tabesne cadavera solvat
An rogus, haud refert——
Hos——si nunc non usserit, ignis,
Uret cum terris, uret cum gurgite ponti:
COMMUNIS MUNDO SUPEREST ROGUS, *ossibus astra*
Misturus——

But the words of Ovid himself are still more remarkable;

* Μυθου μεν χημα εχον λεγεται, το δε αληθες εστι, των περι γην και ουρανον ιοντων παραλλαξις, και δια μακρων χρονων γινομενη των επι της γης πυρι πολλω φθορα.

remarkable; because the notion of a future conflagration is recognised as a *tradition* established of old——

> *Esse quoque in fatis reminiscitur, affore tempus*
> *Quo mare, quo tellus, correptaque regia cœli*
> *Ardeat, et mundi moles operosa laboret:*
> *Tela reponuntur manibus fabricata Cyclopum.*
>
> MET. lib. 1.

The last line seems to hint at the physical sources of the conflagration itself: the fabulous habitation of the Cyclops was in Etna and other burning mountains, and their office was to forge thunder-bolts: so that the fires reserved for this purpose, or, as Ovid expresses it, *laid up in store*, and ready for use, like the instruments of war in a repository of arms, are those of the heaven above and the earth beneath; the bolts of lightning, and the eruptions of subterraneous fires. As at the deluge all the fountains of the abyss were broken up; so at the conflagration, all the *fountains of fire* shall be opened, the volcanos of the earth shall pour forth all their hidden stores, and new ones shall be opened in all places. And as the rain from heaven concurred with the waters of the deep, when the world was to be drowned; so shall the fires of the sky co-operate with those of the earth,

earth, when the world is to be burned; as they were once employed in the destruction of Sodom.

If it should be asked, how the Heathens came by this article of their philosophy; I know not how the question can be answered, but by deriving it from sacred tradition, the undoubted source of their other doctrine concerning the flood; the traces of which tradition have been perused of late with so much labour and ingenuity by the learned Mr. Bryant, in his Mythological Work. For though they might possibly infer (which yet I believe they never did) the reality of a deluge, from the proofs which the earth itself affords of it; they never could know (what they have asserted) that it extended to the whole world, but upon the authority of some tradition, handed down to the posterity of Noah, or taken from the Scripture. It is pretty clear they were indebted both to tradition and revelation; to tradition for the general notion of the fact, and to revelation for the particular circumstances.

Their doctrine concerning the conflagration must be ascribed to the same original: there is no occasion for us to suppose that human philosophy invented what was actually

published to the world on better authority in writing. The prophet had proclaimed, before the time of Plato, and that in the most explicit terms, that there was a *great* and *dreadful day* at hand, which should *burn as an oven**, when judgment should overtake the inhabitants of the earth. The appearance on Mount Sinai must have suggested the same idea: for if an Heathen philosopher could understand a burning mountain as a denunciation of the future burning of the world; surely an Hebrew philosopher, if he were blessed with an equal degree of sense and foresight, might infer the general visitation of the world, from the partial visitation of the Hebrews, when their God was revealed to them in flaming fire in the wilderness. All the terrors of fire, and smoke, and lightning, and thunders, and an earthquake, then assembled together, composed a scene to which nothing upon earth can be compared but the terrors of a volcano, as they have been described to us by those who have been eye-witnesses of a grand eruption. We may suppose it is with a view to this moral use of the terrible scene which attended the delivery of the law, that the prophet

* Malachi, ch. iv, ver. 1.

phet reminds us of Horeb when he foretells the conflagration of the world*.

There is a time approaching, when all philosophy shall have an end, but that which is related to divinity; and therefore we can offend no serious person if we mix a little divinity with our philosophy, now the order of our discourse has led us fairly up to this great subject.

The conflagration, being an article of faith, must be received on the authority of revelation; but still our reason, if it is so disposed, may find something satisfactory to assist us in our belief; and there can be no harm in accepting the collateral evidences of philosophy, if we make a proper use of them.

Here it might be sufficient for us to understand, from the natural proofs of the deluge, that the world having once been destroyed by water, according to the word of God, the same authority is therefore sufficient to assure us of its future destruction by fire. But philosophers may go a step farther. Modern discoveries have taught us, that all bodies, solid and fluid, the sea, the earth, the air, the clouds, are replete with a subtile

* Malachi, ch. iv. ver. 4.

subtile and penetrating fire; which, while it is at rest, gives us no notices of its existence: we live in it, and move in it, and its power, of all other material things, (for matter it certainly is,) comes nearest to the power of God. When it is excited to action, it turns into a consuming fire, which no substance can exclude, no force can resist. The matter of lightning, which seems to be partial and accidental, is universal, and constitutional to the whole system of nature: so that the heavens, which, according to the language of the scriptures, are to *melt with fervent heat*, want no additional matter to convert them into fire; and the earth, and the works that are therein, may be burnt up by that element which now resides within them, and is only waiting for the commands of its Creator. I would not send my reader to every part of Dr. Burnet's Theory for true philosophy or natural history; but his chapters on the conflagration may be perused with pleasure and profit by the most critical judges, and will perhaps leave them better as well as wiser. His thoughts are clear, his ideas strong, his language pure, flowing, elegant, and majestic. When the order of his subject has brought him regularly up to the

the moment of the world's dissolution, he introduces it as follows: "Imagine all na-"ture now standing in a silent expectation "to receive its last doom: the tutelary and "destroying angels to have their instruc-"tions: every thing to be ready for the "fatal hour: and then, after a little si-"lence, all the host of heaven to raise their "voice and sing aloud, LET GOD ARISE: "*let his enemies be scattered. As smoke* "*is driven away, so drive them away; as* "*wax melteth before the fire, so let the* "*wicked perish at the presence of God.* And "upon this, as upon a signal given, all the "sublunary world breaks into flames, and "all the treasuries of fire are opened in heaven "and in earth*."

VII. ON THE NATURAL EVIDENCES OF THE ANTIQUITY OF THE WORLD.

It will possibly be expected we should give some account of the attempts which have been made to ascertain the antiquity of the world from the appearances in nature; as we judge of a man's age by the wrinkles and furrows which time has made in his countenance.

The learned Dr. Halley thought he had hit upon

* Book iii. chap. 12.

upon a principle which would lead to this discovery, and carry us back, almost with demonstration itself, to the true date of the creation. He laid it down as a principle, that the water of the sea derives all its saltness from the land; that a small proportion of salt is washed down continually by rivers into the sea; and as the sea parts with its water by evaporation, while the salt is not evaporated, the sea must in tract of time retain more and more of it, till it has acquired that degree of saltness which we now find by experiment. Therefore, if the increment of saltness could be found for any given term of years or ages, we should then be able to work backwards by the rule of proportion, and discover the time when the sea first began to grow salt, that is, when the world began to exist. And thus he judged, that the world would be found *much older than many have hitherto imagined:* by which it was insinuated, that if the principle could be pursued, the chronology of the scripture would be superseded; the drift of this, and other like speculations, being to weaken the authority of the Bible.

His idea of *salting* the sea with *fresh water* is rather uncommon and original; but great men have their privileges. The argument, however,

however, in more respects than one, is defective in point of calculation; for, let it be that the sea evaporates into fresh water, and that so the salt it contains is left behind, we are still no nearer than before, unless, while the sea is losing fresh water by evaporation, we can stop all the rivers, so that no fresh water shall be added in the mean time. Dr. Halley, as we have seen above, maintained, on another occasion, that the reception of fresh water by the sea is equal to the quantity lost by evaporation. Here he seems to have forgotten that the rivers will all be running on, and bringing in fresh water, while the vapour is rising from the surface; and so, when things are laid together, the whole argument will end in a cypher. I am rather inclined to think, and I apprehend many will be of the same opinion, that the postulatum on which the argument is built, is itself erroneous; namely, that the water of the ocean was fresh at the beginning of the world. The saltness of the sea is as necessary to the constitution of that element, and to the well-being of the terraqueous globe, as the redness of the blood is necessary to the improvement of the serum in the animal system. The sea is no more salt by chance, than the blood is red by chance.

chance. It was a wise provision of the Creator, that the immense body of waters, which occupies more than two thirds of the globe, should be thus salted and seasoned for its own preservation, and for the salubrity of the atmosphere; on which account the ocean is more salt in the seas under the torrid zone, where the heats are more productive of putrefaction; and the saltness decreases as we approach to the colder regions of the pole: all of which indicates a design, and teaches us that the saltness of the sea is a work of Providence, which does nothing in vain. If it is true that the agitation and ventilation of the sea is not sufficient, in vast tracts and deep waters, to keep it sweet without a due proportion of salt, then Dr. Halley's scheme would have poisoned the world *.

Another argument for the great antiquity of the earth, and tending to throw its chronology into obscurity, has been drawn from the condition and appearance of the succes-

* There is in the Philosophical Transactions another paper by Dr. Halley, on the Deluge, which contains many crude reflections on the sacred account of it in the book of Genesis. This paper was laid aside for thirty years, and was then unfortunately brought out of its obscurity, and printed. But it can add little honour to the many rational and valuable collections of the Royal Society.

sive beds of lava, with vegetable soil between them, in the neighbourhood of Vesuvius and Etna, which indicate many ancient eruptions, so far distant from each other in time, as to carry us back to periods more ancient than the common æra of the world.

This argument, to make the most of it, is taken from partial observation, from whence no true judgment can be formed. The words of Sir W. Hamilton, in his curious and entertaining letters on Vesuvius and Etna, are these: "I do not pretend to say, that a just "estimate can be formed of the great age of "volcanos from this observation, but some "sort of calculation might be made *." From the appearance of the earth at Herculaneum, an observer might think he had found circumstantial evidence to prove, against the truth of history, that there have been but six eruptions since the time of Pliny; because there are six successive coverings above that erupted matter which then destroyed the city: but history informs us of twenty-eight; and as seventeen of these were recorded within the last hundred and fifty years, it is not improbable that there have been many more. We may soon run wild into very strange

* P. 98.

strange speculations, if we oppose our own views of natural appearances, which are very contracted and imperfect, to the truth of historical records. I shall not wonder if some philosophers were to contemplate volcanos, till they become ripe for persuading us, that the world was *burned*, when we suppose it to have been *drowned:* and some may be apprehensive of a second deluge, when others are looking for the conflagration. There is no end to the conjectures which have been and will be framed by those, for whom vulgar truth is not good enough. Some will go out of the road, for no other reason but because it has been beaten by their inferiors. We have seen of late the fantastic chronology of the barbarous Gentoos put into competition with the authority of Moses; though their relations abound with puerile extravagances, scarcely to be exceeded by the tales of the fairies *.

Abbé Fortis, the learned traveller, who has lately favoured the public with an account of the curiosities of Dalmatia, particularly the fossil bones, expresses no particular belief of the one great deluge which is authenticated by

* The reader will have pleasure in consulting a very useful pamphlet on this subject by the learned and rev. Mr. Costard.

by scripture and tradition, and confirmed by observation; but has adopted the wild notion, so fashionable of late with some foreign philosophers, of a succession of deluges, which happened we know not when, nor why, nor where; and imagines there was a time when a fresh water river ran over an island two hundred feet high, with fossil bones and marble in the base of it, lying out at sea at a distance from the continent; because the sand of the island has the appearance of river sand. This and other like wonderful revolutions, he thinks, must have required such prodigious tracts of time to have been brought about in the way he imagines, that a few successions of such changes will carry us back to periods of unfathomable antiquity; and thus philosophy may tempt us to suspect that the world is ten times as old as history has declared it to be. I fear we should be led to some strange conclusions, should we assent to the Abbé's rule, and suppose rivers to have flowed wherever there is an appearance of river sand *. Profane history carries us backward nearly

* It was inferred by a certain writer, that the city of Norwich was once a sea-port, because fossil sea shells are found in the soil: but this argument would make sea ports in most of the inland countries of the world.

nearly to three quarters of the whole distance between the present time and the flood of Noah; and we read but of one very extraordinary revolution in the face of the earth; which was rather an acute and sudden distemper in the earth, than a slow and chronical change: in other respects, the face of the globe, in those parts which were known to ancient geographers and historians, seems to be nearly such as it was in the earliest ages.

Here it is worth observing, by the way, how wise men, in different ages, take different ground, and, as it were, change sides, in their attempts to invalidate sacred truth. To prove there should be no final judgment, they objected formerly, that "*all things continue as* "*they were from the beginning of the crea-*"*tion. For this they willingly are ignorant of* "*—that the world that then was, being over-*"*flowed with water, perished**." Now they depreciate the sacred account of things, by supposing deluges upon deluges; convulsions and revolutions; rivers upon mountains; countries, once inhabited, now under the bottom of the Mediterranean sea; and sea-ports in the middle of a continent; as if the truth of history could be overlaid by the rubbish of

* 2 Pet. iii. 4, 5, 6.

of a volcano, and twenty visionary floods could drown the deluge of the Scripture.

According to the Sacred History and Chronology, there was, about four thousand years ago, an universal revolution in the terraqueous globe, by means of what the sacred language has called מבול; wherein, according to the sense of that term, all the elements, all the productions of the land and water, were *mixed* and *confounded* together*; and the effects of this confusion are every where observable at this day. From the date of that fact a new æra of the world commenced: and that it actually did commence about the time above-mentioned, there is much concurring testimony to prove; and nothing appears that is inconsistent with it.

The remains of vegetables, animals, and marine bodies, are in such a condition now, as we might expect to find them in, after such a period as is reported to have intervened.

The

* The same idea occurred naturally to Virgil when he had the subject of the Deluge before him—

——*Tellurem* effundat *in undas*
Diluvio miscens.————ÆNEID. 12, 204.

See the learned Mr. Parkhurst's Hebrew Lexicon under the word בל.

The progress of knowledge, arts, commerce, navigation, and astronomy, demonstrates this period to lie within the limits of memorial antiquity.

Historical records carry us back step by step to ages of primitive simplicity; to the peopling of the present world, the dispersion and settlement of the nations which now inhabit it; to a time when there was but one sort of government upon earth, the Patriarchal and Monarchical; and that so uniform that it must have been diffused from one common source, and propagated as it were from some one centre of the habitable world.

The rites and traditions of idolatry, so uniform among distant nations, and all of them recognizing the doctrines of revelation, afford us another proof that mankind had never been separated long enough to forget what they had learned, when they were comprehended within the bounds of one society. We have other collateral evidences to the same purpose, from the history of language and letters. If we search into remote times, we come to an age when language was much more simple and natural than at present, and alphabetical letters were unknown. The most ancient language of the world seems to have consisted of

monosyllables, perhaps entirely so in its primitive or radical terms; and some learned men have thought, that the form of the Hebrew language in this respect, exclusive of other arguments, is a presumptive proof of its primævity. The Chinese, who have departed from the ancient form less than many other nations, either through pride, stupidity, or want of a due intercourse with other people, have to this day a language of monosyllables, and retain much of the hieroglyphic method in their writing; which consists, not of alphabetical letters, but of figures, which in their first intention were images of *things*, and nearly allied to the hieroglyphics of the ancient Egyptians, as some learned men have found of late by comparing them together *.

Time,

* Nos characteres sont composès de symboles et d'images, & ces symboles & images ne tenant a aucun son, peuvent etre lus dans toutes les langues, & forment une sorte de peinture intellectuelle, d'algebre metaphysique & ideale, qui rend les pensees, & les represente par analogie, par relation, par convention, &c. See Memoires concernant L'Histoire, &c. des Chinois, p. 24. The literary History of China has been elucidated of late by means of two young students, who came over from China to Paris for an European education, and returned well learned and qualified to make the proper researches into the antiquities of their own country. The materials communicated by them have been digested by the

missionaries

Time, in its progress, has drawn out the words of many derivative languages to a greater length, by introducing a multiplicity of artificial compositions and combinations, which have made the science of language more complex and difficult than it was at first. Yet the world is not so old, but that our researches carry us back to what may be called the birth of letters and language; the history of which is like a register-book, and may be pleaded against those who would falsify and disguise the true age of the world.

From the state in which the people of America were discovered by the Europeans, it appears that the first inhabitants of that continent must have gone off from a society which had not attained to a learned and polished state; and therefore must be supposed to have been in a kind of infancy, like people who were beginning the world; yet their separation was still within the reach of historical tradition.

So that there is in fact nothing upon earth that

missionaries of Pekin, and one volume has been published at Paris, which was sent over to me as a present by a learned member of that university. In the plates at the end of the book, the analogy between some Chinese characters and the Egyptian hieroglyphics is made evident to sight.

that agrees with the notion of immemorial antiquity in the *present world;* and all conjectures to that purpose can have nothing to rest upon but hypothetical conclusions, too hastily deduced from imperfect observation. It is too obvious that there is in the present age a lamentable propensity to catch at every little circumstance that may be turned to the disadvantage of the sacred records, and throw things, either by the help of fire or water, or any of the elements, into that obscurity which may be favourable to philosophical scepticism. But sceptics are not constant and uniform in their scruples: some new magazine of objections is opened in every age, as if they had no confidence in the old ones; and it is frequently seen, that the mind will yield to the weakest surmises on one side, while it is proof against the strongest arguments and demonstrations on the other.

VIII. On the Distribution of Land and Water in the Terraqueous Globe.

There is one curious part of our present subject which still remains to be treated of; and it would of itself open to us a large field for

for speculation. The peculiar distribution of the land and water over the face of the globe is worthy of observation; together with the relation and proportion they have to each other. If the learned reader will please to take a terrestrial globe out of its frame, with its brazen meridian, to inspect it as a map, he will discover that the land and water are generally *contrasted* to one another on the opposite sides of the world; by which it is meant, that if there is land on one side, it is answered by water in the antipodes. Thus, for instance, the circumpolar parts of the northern hemisphere consist chiefly of land; but the circumpolar parts of the south consist almost entirely of water. It was formerly thought, that as there is so much land about the North Pole, other land would be found to balance it about the South Pole: but the late discoveries in navigation have put it beyond a doubt, that no such land is to be met with: nor ought it to have been expected; for land on one side is balanced by water on the opposite. If you bring the meridian of the *Cape of Good Hope* under the brazen circle, or universal meridian, observing that this meridian passes through the heart of the continents of Europe

rope and Africa, you will find that the opposite part of the meridian passes through the middle of the great South Sea. When the middle of the northern continent of America, about the meridian of Mexico, is examined in the same way, the opposite part passes very exactly through the middle of the Indian ocean. The southern continent of America is opposed by that eastern sea which contains the East India islands. The southern continent of New Holland is opposite to the Atlantic ocean. This alternation, if I may so call it, between the land and sea, is too regular to have been casual; and if the face of the earth was so laid out by design, it was for some good reason. But what that reason may be, it will be difficult to shew. Perhaps this disposition may be of service to keep up a proper balance; or, it may assist toward the diurnal rotation of the earth, the free motion of the tides, &c. or the water on one side may give a freer passage to the rays of the sun; and being convex and transparent, may concentrate, or at least condense, the solar rays internally, for some benefit to the land that lies on the other side. But these are questions too abstruse for me to determine; and perhaps they may always

always remain amongst those *secret things* which *belong* to him who hath *measured the waters in the hollow of his hand, and comprehended the dust of the earth in a measure, and hath weighed the mountains in scales and the hills in a balance**.

Superior Dignity of the Northern Hemisphere.

Another remarkable phænomenon, and more level to our understandings, is the manifest superiority of the northern hemisphere of the world above the southern. It has more land, more sun, more heat, more light, more arts, more sense, more learning, more truth, more religion. The land of the southern hemisphere, that is, the land which lies on the other side of the equinoctial line, does not amount to one fourth part of what is found on the north side; as every person must see, who will be at the trouble of making the comparison.

The sun, by reason of the eccentricity of the earth's orbit, and the situation of the aphelion, makes our summer eight days longer than the summer of the other hemisphere; which in the space of four thousand years, (for so long it is since any universal change has

* Isa. xl. ver. 2.

has taken place in the earth,) amounts to upwards of eighty-seven years; and so much more sun has this hemisphere enjoyed than the other. What effects may have been arising gradually in all that time, we cannot ascertain; but such a cause cannot have been without its effect: and I think it is allowed, that the temper of the earth and atmosphere, in the highest latitudes of the north, is much more mild and moderate than in the correspondent latitudes of the south. The dreary face of *Staten-land*, with the weather-beaten Cape of South America, a climate so severe as scarcely to admit of any human inhabitants, is no nearer to the Pole than the northern counties of England: but the difference in the atmosphere and in the aspect of the earth is almost incredible: and this is the more remarkable, because there is no mountainous country betwixt that and the Pole to account for the icy blasts that prevail there.

But it is also farther observable, that the northern hemisphere is better provided for by night as well as by day. The stars of superior magnitudes are much more numerous on this side the equinoctial than on the other. We have nine stars of the first magnitude; and

and they but four. And the stars of the Great Bear, so conspicuous in this hemisphere, have nothing to equal them about the other Pole. When the sun is remote from us in the winter, our longest nights are illuminated by the principal stars of the firmament. When the sun enters Capricorn, there come to the meridian about midnight, the whole constellation of Orion, the brightest in the heavens, and so called from an Eastern word which signifies *light**, containing two stars of the first magnitude, four of the second, and many others of inferior sizes: and upon the meridian, or near it, there are four more stars of the first magnitude, Capella, Sirius, Procyon, and Aldebaran. No other portion of the heavens affords half so much illumination; and it is exactly accommodated to our midnight, when the nights are longest and darkest. If the mid-winter of the southern hemisphere be compared, the inferiority of the nocturnal illumination is wonderful, and will be evident to any person who examines the problem upon a celestial globe.

Intel-

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Intellectual Superiority of the Northern Hemisphere.

Though it will carry us a little beyond the bounds of physics, the parallel is so glaring between the natural and intellectual superiority of this part of the world, that our time will not be lost while we reflect upon it; though it must occur to the learned reader without any previous admonition. Here the arts of war and of peace have always flourished; as if this part of the globe had been allotted to a superior race of beings. Asia and Europe, from the remotest times, have been the seats of science, literature, eloquence, and military power; compared with which, the southern regions have ever been, as we now find them, beggarly and barbarous; possessed by people stupid and insensible, illiterate and incapable of learning. Where are the poets, the historians, the orators, the philosophers, of the southern world? We may as well search for the sciences amongst the beasts of the wilderness. Then in the military arts, what comparison is there betwixt the naked black woolly-headed Caffre, with his miserable javelin, and a champion of the North in complete armour? or those

those soldiers who conquered the world under Alexander and Cæsar, and were as eminent in learning as in arms? What is the artless hut of a savage family, to the architecture of Solomon's temple, with its glorious furniture; or to the sacred buildings of Greece and Rome, which were imitations of it? All the inventions, by which mankind have done honour to themselves in every age, have been confined to this side of the world. Here the mathematical sciences have flourished; printing has been found out; gun-powder and fire-arms invented; navigation perfected; magnetism and electricity cultivated to the astonishment of the wisest; and philosophy expanded by experimental inquiries of every kind. There would be no end, if we were to trace this comparison through all the several improvements which may be comprehended under the name of Humanity; for here we have every thing that can adorn human life, and there they have nothing.

But the difference is most conspicuous when we compare the North and South in point of *religion;* to which, indeed, that pre-eminence is owing on our side, which has extended to every other branch of social ci-

 vilization

vilization and intellectual improvement. It is notorious at this day, that arts and learning flourish to the highest degree in those countries only that are enlightened by Christianity; and no-where so much as in this kingdom, where that religion is established in its purest form. May it long continue! and may we know our own felicity in the enjoyment of it! for it is undoubtedly the sun that gives light to the mind; the vital spirit that animates the human understanding to its highest achievements; though many have been indebted to it, without being sensible of their obligation, or without confessing it: and others have turned against it that light which they borrowed from itself! Let us trace the diffusion of this light in the world. After the flood, when the ark had rested on the mountains of Armenia, Noah and his family, and with them the church and the true religion, settled in the countries adjoining to the Euphrates; the quarter where Paradise, according to the sacred account, had been placed at the first peopling of the world. Syria and Egypt were the first seats of wisdom and learning: from them the light of knowledge travelled westward to Greece; from Greece to Italy;

and when Christianity had taken its course in the same direction, the whole face of Europe was soon changed. The barbarous nations from the North poured in upon the Roman provinces; for plunder and settlement, as they thought; but the Providence of God translated them for civilization to the countries enlightened by the Gospel; and they who were heathen Goths and Vandals, are now Christians in all the divisions of the ancient Roman empire. The people of Britain were in a savage state till Christianity reached them; and now, with the farther lights of the Reformation, and the free use of the Scripture, they are become the first people in the world for every kind of improvement. Their present danger is from an insolent abuse of superior knowledge. The ostentatious affectation of novelty, now so much sought after, makes learning a labyrinth, where there is endless multiplicity of matter, with little light and less profit.

The posterity of Ham moved southward; carrying with them the false religion of idolatry from the beginning: and the farther they strayed from the residence of the church and the true religion, the deeper they sunk into ignorance. Wheresoever they went,

whether to the Cape of Africa, or to the Atlantic Continent, they propagated the impious and sanguinary rites of human sacrifice: they lost all the treasures of the mind, and all the ornaments of life; all arts, and all knowledge: so that in the extremities of their emigrations we find them but little superior to the brutes, and in some respects more degenerate; because no brutes feed upon their own species, like the canibals of the South Sea, and the American Indians.

The Northern hemisphere, then, whatever preference it may have in a physical capacity, has been much more honoured by the superior advantages of learning and religion. Here knowledge first began to be diffused, and the world itself was first inhabited, in the finest climates of the earth, which are about the latitudes of 36°, &c. north. Here the church was first settled; and the Hebrew nation, rising by degrees till the reign of Solomon, formed a wise, wealthy, and splendid kingdom, long before the powers of Greece and Rome were heard of. Here the light of Christianity was afterwards manifested, and with it the lights of learning have been extended to parts where they were never known before, till both of them reached to the utmost

most boundaries of the West, in the once unknown regions of the Atlantic world.

As reason gives to men the power over brutes, so the endowments of the mind set some men above others; therefore literature and political power have gone together from the rising to the setting of the sun. The first monarchies were in the East; after which the seat of empire was in Greece; then in Italy; then in the many powerful kingdoms of the West; and now, the provinces that are members of the English monarchy think themselves able to contend for power in America.

How this matter, which we have now been considering, may appear to others, I know not: to me, the coincidence between the natural and intellectual advantages of the northern hemisphere is not accidental. I look upon one of these as a testimony to the other; and if so, both together must bring us to this conclusion, that *known unto God are all his works from the beginning of the world.* As they appear and succeed in tract of time, there is an uniformity between them which directs our attention to the common Author of them all; and this is the proper end of all true philosophy. Who cannot see,

that the great disproportion between the land of the two hemispheres is agreeable to the designs of Providence? For, had the South been as habitable as the North, it had only been filled with a miserable people, remote from the light of truth, and consequently abandoned to ignorance, idleness, sensuality, bloodthirstiness, the vilest cruelty of superstition, and every thing that can disgrace the human species. It was therefore an act of mercy to contract the bounds of their habitation; and the whole comes at last to this, that the Southern world is the least, because it is the worst. Which observation leads us to another, and with that I shall conclude the present Discourse.

When we take the whole globe together, the disproportion between the land and the sea is almost as great as between the land of the South compared with that of the North. The sea occupies at least twice as much of the earth's surface as the land, and of that land vast tracts are desert and unfit for human habitation. So that the habitable world might have been more than three times as large as it now is; and consequently, the inhabitants might have been more than three times as many in number. It is obvious to ask

ask ourselves the question, why so much room is lost in the world? How comes this to pass, if the multiplication of life, and the diffusion of physical happiness, were primary objects of the Creator's attention? I fear we shall find no rational answer, but from the present depravity of the human race, Had mankind been better, the world would have been fuller of them. And the sentiment is agreeable to what we are taught to expect at the renovation of all things: for when the first earth shall pass away, and a new heaven and new earth shall succeed, wherein there will be nothing but good, there shall be NO MORE SEA, *Rev.* xxi. 1.

IX. A SHORT VIEW OF THE HEATHEN COSMOGONIES, SUPPLEMENTARY TO THE NATURAL HISTORY OF THE EARTH.

As it may be of some service to truth and literature, especially with the younger sort of students, I have frequently taken occasion to touch upon the sentiments of the heathen philosophers, concerning the subjects that have come before us. Some doctrines, of great value, are of great antiquity;

and common notions of things preserved in the world are always worth attending to, if it be with no other view than to keep us from striking into new paths of groundless refinement, which the mind is too apt to fall into, through an impatient desire of novelty. In this present subject relating to the generation of the world, we cannot expect to find much, on two accounts; first, because the subject is beyond the reach of human investigation; and secondly, because there was an atheistical opinion gone abroad very early, that matter was eternal, and that the world had no beginning. Yet such was the influence of tradition, that it prevailed in a great measure against this false philosophy, and many notices have been preserved of the world's original, especially by the poets; and when the knowledge of the Mosaic system began to be revived by the publication of the Hebrew Scriptures in the Greek language, the Heathens, through a spirit of competition, and a desire to have it thought that all wisdom originated among themselves, began to be more busy than before in delineating their cosmogonies, which were a mixture of tradition, philosophy, and idol-worship.

The

The cosmogony given by Ovid in his Metamorphoses, is modern in comparison of some others, and is so near to the Mosaic account (*verbis ad Mosen proxime accedentibus*, says Grotius,) that it seems to be almost a poetical version of it, with some alterations and additions from the vulgar stores of Heathen theology. Other authors, far more ancient, agree in the general idea of the world's original; that it arose from a formless chaos; that darkness was before light; and that a boundless ocean, or great deep, was the source of all things: and the names they have used shew that their fables have an alliance to the Mosaic history of the creation, though it may be difficult to say how that alliance came about, and at what time it commenced. The cosmogony of Hesiod, who was either very near to the times of Homer, if not his contemporary, is the most ancient; and posterior authors seem in a great measure to have followed him. He tells us, in his poem on the Generation of the Gods, that "first of all was Chaos; and that Night and Erebus were begotten of it; that out of Night, engendering with Erebus, the ether and day-light proceeded; and that after these,

these, the earth and the mountains were formed *."

Primæval Darkness.

Lucian, in his Philopatris, has preserved a like passage from Aristophanes to this effect †; "Chaos and Night, and black Erebus, and the boundless Tartarus first existed, when there was neither earth, nor air, nor heaven; but Night with its black wings laid an egg in the bosom of Erebus, and Love (or a principle of union) sprang up, &c." Grotius ‡ remarks upon this, that it is plainly derived from the tradition of the Phœnicians, with whom the ancient Ionians had frequent commerce; and the terms

* Ητοι μεν πρωτιστα Χαος γενετ'
Εκ Χαος Ερεβος τε μελαινα τε Νυξ εγενοντο,
Ους τεκε κυσσαμενη, Ερεβει φιλοτητι μιγεισα,
Γαια δε τοι πρωτον μεν εγειναλο ισον εαυτη
Ουρανον αστεροενθ' ινα μεν περι παντα καλυπτοι
Οφρα ειη μακαρεσσι Θεοις εδος ασφαλες αιει·
Γειναλο δ' ουρεα μακρα, &c.

† Χαος ην και Νυξ Ερεβος τε μελας πρωτον, και Ταρταρος ευρυς
Γη δε αηρ, ουδ' ουρανος ην· Ερεβου δ' εν απειρασι κολποις
Τικτει πρωτιστον υπηνεμιον Νυξ η μελανοπτερος ωον,
Εξ ου περιτελλομεναις ωραις εβλαστησεν Ερως ποθεινος.

‡ See Grotius de Ver. Edit. Glasg. p. 34, Note ii.

terms are deducible from the Phœnician language, which was very near to the Hebrew, as appears from one curious instance among many others, discovered and explained by Bochart, from the Pænulus of Plautus; but it would be foreign to our present purpose to dwell upon it. The term Chaos is taken from חשך the darkness that is said to have been upon the face of the deep. Erebus is from ערב the evening; and Tartarus, whether it be Phœnician or not, is certainly an exotic word, not reducible to the Greek. Phurnutus, a Greek writer on Mythology, who has commented upon the words of Hesiod, attempts to derive these words from the Greek; as Chaos from χυσις a pouring out, or καυσις the burning of fire, and Erebus from ερεφεσθαι to be covered; but it cannot be done without violence and absurdity.

The Earth compared to an Egg laid in Darkness, and hatched by the Wind.

The Egg, in the verses of Aristophanes, is the orb of the earth, so called from its figure and construction, and from a traditional notion of that Incubation of the Spirit, expressed by the word מרחפת, which is applied to the *brooding* of a bird over her nest.

 The

The heathens were fond of representing the earth by an egg; Sanchoniatho, in his Cosmogony, speaking of the planets, as Bishop Cumberland understands him *, calls them Zophesemin, which signifies, *inspectors of the heavens*, and describes them as formed in the shape of an egg, and produced from mud and water, a formless mass, like that from out of which the earth was generated. The ancients had probably a philosophical view to the structure of the earth in this analogy; for an egg is composed of solids and fluids, disposed in a peculiar manner like those of the earth, which has a solid habitable crust, like a shell without side, and has fluids within. The fertility of the earth might also be alluded to; for as an egg has a principle of life, so the earth is the mother of all those productions which arise from it through the incubation of the circumambient elements. It is worth remarking, in the words of Aristophanes, that the egg of primæval nature is called *ὑπηνεμιον*, *subventaneum* †; by which it is meant, that this egg was conceived of the wind, and brooded by it; which agrees with

* See his Rem. on the Hist. of Sanchoniatho, p. 21.

† ——————— Ερεβῳ δ' εν απειρασι κολποις
Τικτει πρωτιστον ὑπηνεμιον Νυξ η μελανοπτερος Ωον.

with what is said of the Spirit in the Mosaic account of the creation: and the like sense was hieroglyphically expressed by what Mr. Bryant, in his Mythology, calls the mundane egg of the Egyptians and Tyrians; this was the figure of an egg, with a serpent twisting itself all over it, and embracing it, to denote the operation of that invigorating spirit which at first cherished and perfected the world by its incubation. This hieroglyphical use of the serpent agrees with and confirms what was observed at p. 502, vol. ix. concerning the serpent as a symbol of the air. For this figure of the serpent and mundane egg, see Mr. Bryant's Work, Vol. II. Pl. IV. p. 242.

Matter of the Earth fluid at first.

The heathen authors of best authority and greatest antiquity, who speak of the begining of all things, agree in this, that the materials of the earth at first floated in disorder as a fluid abyss of water, and that the matter of the heavens was in a state of darkness. The learned Dr. Cudworth, in his Intellectual System, produces a remarkable passage from Aristotle, wherein he allows "that the very ancient physiologists, most remote from the

the age in which he lived, made the Ocean * and Tethys the beginning of all generation; for which reason, the oath of the Gods is said to have been, By Water! which the poets call Styx, as being that element from which they were all derived; for an oath ought to be by that which is most honourable, and that which is most ancient is most honourable." This, by the way, is a proof that the heathen deities were no other than the elements and parts of nature, because, by their own confession, they were posterior in their order to the formation of the world.

The Physical Trinity of Hermes.

And here, as it is an article of great curiosity, and will give some light into the heathen cosmogonies now before us, I hope it will not be thought a digression if I present the reader with a copy of the Hermetic creed of the Egyptians, which I had occasion to take into consideration several years ago, in an argument with the author of an Essay on Spirit.

* Hence Virgil has called the Ocean, *The Father of all things;*

——— *Simul ipsa precatur*
Oceanumque patrem rerum, *nymphasque sorores.*
Georg. iv. 380.

Spirit. The Chevalier Ramsay, an eminent mythologist, in his Travels of Cyrus, gives us a very imperfect specimen of this wonderful creed; but Iamblicus delivered it at large, in terms which I shall translate as faithfully and literally as I can: "Before all "things that really exist, and before the "beginning of all time, there is one God, "prior to the first God and ruler of the "world, remaining immoveable in the soli- "tude of his unity; for neither is intelli- "gence immixed with him, nor any other "thing. He is the exemplar of himself; "the Father, the self-begotten God, who is "the only father, and is truly good. For "he is the greatest and the first, the foun- "tain of all things, and the root of all pri- "mary intellectual forms. But out of this "one, the God that is self-sufficient shone "forth of himself: for which reason, he is "the father of himself, and all-sufficient; "for he is the beginning, and the God of "Gods. He is unity from the only one; "before essence, and yet he is the beginning "of essence, for from him is entity and es- "sence; on which account he is celebrated "as the prince of intelligence. These are "the most ancient principles of all things, "which

"which Hermes places first in order, before "the etherial, empyrean, and celestial dei- "ties*:" Though all this sounds like divinity, and has even a trinitarian aspect, it is, in fact, nothing more than philosophy; for the heathen deities were the elements of nature; and this trinity, when compared with the testimonies of the heathens themselves, will prove to be a physical one. The *one solitary and immoveable God*, prior to all beings, is the *chaos*, or *first matter* of the world, capable of every form, but without any form proper to itself. This principle is sometimes called *incomprehensible darkness*, as by *Damascius*, *μια των ολων αρχη σκοτος αγνωςον*, the same that in the Orphic hymns is called *Night, the begetter of Gods and men.* At other

* Προ τῶν οντως όντων, καὶ τῶν ολῶν αρχων, ἰστι Θεὸς εις, πρωτος και τȣ πρωτȣ Θεȣ και βασιλεως, ακινητος εν μονοτητι της εαυτȣ ενοτητος μενων; ȣτε γαρ νοητον αυτω επιπλεκεται, ȣτε αλλο τι. Παραδειγμα δε ιδρυται τȣ αυτȣ πατρος, αυτογονȣ, και μονοπατορος Θεȣ, τȣ οντως αγαθȣ. Μειζον γαρ τι και πρωτον, και πηγη των παντων, και πυθμὴν των νοȣμενων πρωτων ειδων οντων. Απο δε τȣ ενος τȣτȣ, ο αυταρχης Θεος εαυτον εξελαμψε· διο και αυτοπατωρ και αυταρχης. Αρχὴ γαρ αυτος και Θεὸς Θεων· Μονας εκ τȣ ενος, προ ȣσιας, και αρχη της ȣσιας· απ' αυτȣ γαρ η ȣσιοτης και η ȣσια· διο και νοηταρχης προσαγορευεται. Αυται μεν ȣν εισιν αρχαι πρεσβυταται παντων, ας Ερμης προ των αιθεριων και εμπυριων Θεων προστατει, και των επȣρανιων.

other times he is called *Proteus*, first matter, which originally is under no form, but capable of assuming all shapes, according to the infinitely various modifications of matter; whence the poets have improved him into a fabulous character, that practises all kinds of transformations. In a fragment of Epicharmus, Chaos is called the first of Gods, Χαος πρωτος των Θεων, which is a proof that this deity is not a *spiritual*, but a *physical* principle, and that all the Gods of these philosophers were supposed to arise from the matter of the world being all posterior to the chaos. No God could exist *before the first*, as in the Hermetic theology, unless we understand by it the self-existent matter of the chaos. This deity is *immoveable*, because he comprehends the primary substance of all nature, which fills all things, and cannot change places with itself; and while all other things are in a flux state of generation and dissolution, this substance, the *substratum* of all things, is itself indissoluble and unchangeable; the whole secret of which theology is fully expressed in these lines of *Manilius:*

> *Omnia mortali* mutantur *Lege Creata,*
> *At* manet incolumis *mundus, suaque omnia servat,*

Quæ nec longa dies auget, minuitve senectus,
Nec motus *puncto currit, cursusque fatigat.*
Idem *semper erit, quoniam semper fuit idem.*
Non alium vidêre patres aliumve minores
Aspicient: Deus *est, qui non mutatur in ævum.*

Manil. Astron. I. 515.

Though some expressions in the above Hermetic form of doctrine are obscure, they are explained in what follows: that this God is the *fountain* of all things, the *root* of all primary existent *forms*; which terms must signify that original matter, out of which all visible forms are generated; as the leaves and branches of a tree proceed from its root. In the Orphic Hymns, the name of *Jupiter* is given to this primary substance of nature, and it is said to be the *first*, the *last*, and the *midst* of all things; and I think the sense of the passage will now be intelligible.

Ζευς πρωτος γενετο, Ζευς υστατος αρχικεραυνος,
Ζευς κεφαλη, Ζευς μεσσα, Διος δ' εκ παντα τετυκται,
Ζευς πυθμην γαιης τε και ουρανου αστεροεντος.

He is the *first*, as having existed in a chaotic incomprehensible state, prior to the forms: he is the *middle*, as existing in an intermediate state, *under* the *forms* of visible bodies; and the *last*, as being that ultimate substance into which all formed bodies are

again

again resolved, in that continued round of generation and corruption so much descanted upon by the most early philosophers. he second deity of Hermes is *the Sun*, who *shone forth of himself*, out of the formless matter of the world; as light, in the poetic generation of Hesiod, succeeded to Chaos, Night, and Erebus. This deity was called *Cneph* by the Egyptians, and is confessed to have arisen from *sand and water*; so that he also was no spiritual principle. His name of *Monas*, or unity, is applicable to the sun, because he is but *one*; and the Assyrians, as Macrobius confesses, worshipped the sun under the name of *Adad*, a corruption of the Hebrew or Phœnician *achad*, and Macrobius thus explains it—*ejus nominis interpretatio est* unus. *Sat.* lib. i. cap. 23.

It seems impossible that he should be before *all essence*, and yet be himself *the beginning of essence*: but this may be reconciled by the help of a scholion upon a verse of Hesiod, according to which ὕλη, *first matter*, is to be considered as an unwrought mass of metal; ουσια, *essence*, is the same mass hammered into form and figure; so that the sun, as his substance existed in the formless chaos, was *before essence*; but when

he was self-generated from it, and received a form, he was the *first essence* properly so called, and became the efficient cause of essence in other things: and as sense, or intellect, according to the philosophical creed of the Heathens, was the result of *matter* and *form*, (which doctrine some writers are now disposed to revive, and even to father it upon Christianity.) he was dignified with the attribute of *νοηταρχης the prince of intelligence.*

In the third order, we see the ethereal dæmons, or powers of the heaven, taking their place in the Hermetic theology. We find, therefore, a sort of Trinity among the Egyptians, composed of three parties, first, Matter, the Sun, and the Elements of heaven; the Air, Æther, Stars and Planets. The Pythagorean Trinity was nearly the same with the Egyptian: it consisted of a *first one above all essence*; a *second one*, which is perfect essence, and was called *the Forms*; and a third, which is animal, mental, or intellectual, partaking both of matter and form, and being the result of their union *.

his

* Το μεν πρωτον ἑν ὑπερ το ON και πασαν ουσιαν αποφαινεται· το δε δευτερον ἑν, οπερ εστι το οντως ον, και νοητον, τα

This needs no comment, after what has been said of the Hermetic Trinity. The subject is curious, and might be carried on much farther, but it would break in too much upon our present design. That young scholars may not be deceived with false appearances, and the specious refinements of Deism, which too often fall in the way of students in philosophy, I have judged it useful to set before them, as briefly as I could, this grand mystery of the Pagan theology, this medley of philosophy and divinity; which has been called in by those who did but half understand it, to corrupt the doctrines of Christianity, which have no relation to it, and are wholly of a spiritual intention.

Poppy-heads, why offered to Ceres.

Concerning the structure of the Earth, we find nothing more curious amongst the mythologists, than the *poppy-heads* which they offered to Ceres, as she signified the earth, the mother of all vegetation; in which capacity she was called Δημήτηρ, *all-sufficient mother.* This instance may serve, like many others, to shew how ingenious they were in

 accom-

τα ειδη φησιν ειναι· το δε τριτον, οπερ εστι ψυχικον, μετεχειν τε ενος και των Ειδων. Simpl. in Phys. Arist. fol. 50.

accommodating emblems and illustrations to the views of their philosophy and theology. Phurnutus, a mythological author, gives us the rationale of the custom. "Poppies," says he, "are offered to Ceres for these "reasons; because their heads are round or "spherical like the globe of the earth; and "their surface has prominences, and irregu- "larities, analogous to the hills and vallies "on the face of the earth: within they are "hollow and cellular, like the body of the "earth, which has caverns under ground: "and these cells contain an infinite number "of small seeds, resembling the fertility of "the earth, which inwardly abounds with "the seeds and principles of all its produc- "tions*."

How far the Cosmogony of the Heathens symbolizes with the Cosmogony of Moses.

If we look back to what has been collected from

* Ανατιθεασι δ' αυτη και τας μηκωνας, κατα τον λογον. Το δε γαρ στρογγυλον και περιφερες αυτων παριστησι το σχημα της γης, σφαιροειδους ουσης· η τε ανωμαλια τας κοιλοτητας και τας εξοχας των ορων. Τα δε εντος τοις αντρωδεσι και υπονομοις εοικε· σπερματα δε αναριθμητα γεννωσιν ωσπερ η γη. Phurn. in Cerere. This author is supposed to be the Cornutus mentioned by the poet Persius; his name having been corrupted by Aldus Manutius.

from the Heathens, we shall find that their traditions agree with the sacred account in these following particulars: first, that the earth was originally in a formless state; secondly, that its materials floated confusedly in a watery abyss; thirdly, that the matter of the heavens was *dark* and *stagnant*; fourthly, that the night was prior to the day, or that Erebus, the *evening*, was before the day-light; fifthly, that the world, as *an egg*, was subject to a sort of incubation from the *wind*; sixthly, that *water* was held most sacred by the Gods, because it was *first* of all things. These several particulars of resemblance between the sacred and profane accounts are very remarkable: they are out of the reach of human reason, and could not have been *invented* by the Heathens; therefore they were *borrowed*, and, as such, may be considered as so many testimonies to the authenticity of the sacred account, though not preserved with any such intention. In the course of my reading, I have found that there is scarcely any one miraculous fact, from the beginning of Moses to the end of the Prophets, to which the Heathens have not given their testimony, by pretending to something of the same kind among them-

selves; a step which they would never have thought of taking, unless they had been tempted to it by the vanity of competition. Whoever reads the Greek and Roman poets and mythologists with this view, will soon find enough to convince him of the truth of what I have advanced *.

* See this subject farther considered in a Volume of Letters from a Tutor to his Pupils. Letter XIV.

DIS-

DISCOURSE IX.

On the Appearances, Causes, and Prognostic Signs of the Weather.

THE philosophy of which I have undertaken to treat being chiefly that of the elements, all such observations as relate to the weather ought to have a place in it.

By the *weather* *, we mean the temperature of the air with respect to heat, cold, wind, rain, and other meteors. It is a subject in which all men are interested; and they seldom fail to signify their anxiety by that general practice of bringing it into conversation where no other subject is already in possession. The farmer conforms to it in the course of his labours; the traveller endeavours to regulate his motions by it; and to the navigator it is a matter of life and death.

After

* The word *weather* in English seems to be derived from the Greek αιθηρ, *æther*, which is used by the Greeks

After all the knowledge we can acquire, we shall still be under much uncertainty: but we may proceed so far as to avoid much inconvenience, and even danger upon many occasions. I need not observe how much entertainment must occur to a philosopher from the contemplation of the weather. Here we may see and admire the changes in these elements, which present us with all that is great and wonderful in nature, and which, with a variety little less than infinite, work together for the good of man and the preservation of the world.

If the course of the weather depended absolutely on the course of the year, and the temperature of climates also depended on their situation with respect to the sun, that is, on their latitude; then the weather might be reduced to some regular theory: but all general rules are here subject to many and great interruptions. Some of them depend on causes which we do know; and others on such as we know not. In general, it is true that when we travel to the South, we find more heat as we approach to the equator; and that we shall certainly be starved with cold

as

to signify the weather; as in the following line of *Aratus*:

Ουδεποτε σχεδιως κεν επ' αιθερι τεκμηραιο.

as we get nearer to the pole. In general it is true, that the spring and autumn are mild, the summer hot, and the winter cold: but winds and storms, mists and vapours, showers and rain, are occasional and uncertain in many parts of the world. The North wind is generally cold, because it blows from a cold region; the South is warm, because it blows from the sun; the East is cold and dry, because it blows over the high mountains of the continent; the west is mild and soft, because it blows from the setting of the sun and the Atlantic ocean. But whatever quarter the wind may come from, it is still a matter of inquiry, what vapours and meteors are likely to attend it: so that instead of having certain rules and principles to direct us, as in other sciences, we are driven to the arts of prognostication; and it is a work of time, as well as of much observation and attention, to attain to any skill in it, though all mankind pretend to some degree of it.

The phænomena of nature, which constitute what we call the weather, are vapours, mists and clouds, rain, hail, snow, frost, thunder and lightning, water-spouts, storms, hurricanes, tornadoes, the Aurora Borealis, the

the changes of the winds, some of which are regular and some incidental. The ascent and descent of vapours are facts of very great account in this subject, and they come first in order to be considered.

The Ascent of Vapours.

To account for the ascent of vapours from the earth or sea, it was supposed that the particles of water which lie next the surface are extended into a shell or bubble by the entrance of a warm spirit; and thus being made specifically lighter than the air, they rise up to a certain region, till they find the air as light as themselves, where they remain suspended till the temperature of the air in that region is changed. It was also supposed, that there may be a matter different from air, and much more subtile, with a tendency contrary to gravity, as in the growth of trees and vegetables, whose tendency is against the perpendicular.

All this is very reasonable, and must be near the truth: for it was obvious that fluids evaporate with fire, the motion of which is contrary to gravity; and that almost any matter, by being rarefied with fire or heat, may become light and buoyant to any imaginable

ginable degree. All fluids, when they are warm, will sustain more soluble matter than when they are cold: and the air, like other fluids, does certainly retain much vapour while it is heated by the sun, which it deposits in the night when the sun is absent; therefore heat must be one cause of the ascent of vapour. The case is as plain in the body of the earth or sea as in a boiling cauldron, where we are sure the vapour is carried off by the ascent of fire through the fluid. And to shew that air is not the cause that raises vapour from a boiling liquor, a much more copious dissipation of the vapour is observable, when a vessel of hot water is placed in vacuo. Some have argued, that air acts upon water as a menstruum or solvent; but this will bring us to the same conclusion as before: for how do solvents act? Not by any occult virtue in the solvents themselves, nor in the matter they act upon, but in something adventitious to both. Water dissolves salt as a menstruum, but only under certain conditions; which shew that the power is not in the water, but in something else. Hot water will receive and retain many more of the saline particles than water which is only lukewarm; and when, with a cer-

tain degree of cold, water becomes fixed into ice, it loses its mobility and can dissolve nothing.

I mention it here as a thing very extraordinary, and but lately discovered*, that the salt water of the sea is observed to freeze into fresh water, that is, into ice, which, when dissolved, appears to have lost its saltness. Water with that degree of coldness which is necessary to freezing, cannot retain the sea-salt suspended in it. This effect is of great and happy consequence to those navigators whose business leads them to the seas that lie within the arctic circle.

Heat, which is the grand cause of solution, is also the cause of evaporation †. The earth and sea perspire, when they are heated, like the human body; and nobody ever yet believed that perspiration was owing to the air that surrounds the skin of an animal; although this vapour, like that of rivers and seas, goes off into the atmosphere. It is not the air without, but the heat within, that raises perspiration: the air only receives it, and may do this more or less according to the state it is in with respect to cold and heat,

* See the Transactions for 1776.

† See the Discourse on Fire, vol. ix. p. 232.

heat, rarity or density. The external heat of the sun, shining upon the body, will contribute much to the same effect.

Thus it is in the earth: there is a silent and imperceptible discharge from the pores of the earth; and there is a more violent discharge from volcanos, in a direction contrary to gravity. An internal heat is perceptible in many places at great depths in the earth, and a consequent ascent of vapours toward the surface. I was assured by an intelligent person in the Peak of Derbyshire, that the subterraneous waters in the caverns of that country are observed to fall unusually low on a sudden before any rain is generated in the atmosphere, as if they were wasted on such occasions by a detachment of vapour from them into the upper air; and at the same time, a damp settles copiously on the rocks by the sides of these waters. Many phænomena of the same kind convinced the Alpine traveller, Scheuchzer, that vapours have a direction toward the surface, from the interior parts of the earth, by the agency of a subterraneous heat: "I am firmly persuaded," says he, "that watery vapours are "plentifully raised from the bowels of the "mountain to its top by means of a subter-

" raneous heat*:" and the ingenious Dr. Hales, in his Vegetable Statics, found, by critical observation, that there is a supply of moisture to the superficial parts of the earth, more than can be accounted for from the rain that falls upon the surface.

But whatever part of this effect may be derived from causes underneath the earth, which may prevail in some places and at some times more than others, it is evident to sense that the external heat of the sun's rays have a principal share in it; and since the late discoveries in electricity, we understand better than formerly how evaporation is promoted by elementary fire. This agent is in motion by night and by day, and always endeavouring to restore an equilibrium, which is as constantly interrupted. There are reciprocations in the fluxes of elementary fire, between the body of the earth and the atmosphere, and between some vapours and others, to which many wonderful effects are owing. As this subtile fluid transpires from one body, or from one region, to another, the parts of water are suspended, rarefied, condensed,

* Firmiter persuasus sum, copiosissimas ex imis montis visceribus ad cacumen sublevari caloris subterranei ope vapores aqueos. *Iter. Alp.*

condensed, and precipitated: and its agency is conducted on such principles, that vapours may be raised and dispersed about the atmosphere, even without any sensible increase of heat. A mechanical motion will assist much in the raising of vapours. The ground, when wetted with rain, is found to grow dry very fast with the motion of the wind, by which the parts of water are abraded and carried away into the atmosphere. Thus water, when agitated, will take up the parts of earth or mud from the bottom, and keep them suspended so long as the agitation continues; though the earth would have remained at the bottom as a sediment, and the water would have been transparent, if it had been undisturbed. Even ice itself, hard as it is, is found to part with much of its weight, if its surface is exposed for any time to a cold frosty wind. When the air has more motion, though it has no more heat than it had before, evaporation will be the consequence; and this will give us a plain reason, why the rising of the wind so frequently carries off the rain when it seems to be impending: the same cause which contributes to the ascent of vapour, must also prevent it from falling,

 till

till the atmosphere is so far overcharged, that the vapours can no longer be supported.

Descent of Vapours.

We are, therefore, now to consider the *descent of vapours,* under the several forms in which they return again to water the earth.

The first is that of a mist, or dew. What the sun has raised from the earth in the heat of the day, is retained by the atmosphere so long as the heat of the sun, and the agitation (by which I mean the undulating expansive motion) of the air, continue. It has been already observed, that the motion of the air is instrumental in the raising and sustaining of watery vapours. And we are here to understand not only the motion of the wind; for there is another motion in the air contiguous to the earth, occasioned by the rays of the sun—sometimes it is visible to the naked eye; but in the field of a powerful telescope, this undulating motion of the firmament is so conspicuous, that all objects are in violent agitation, and the line of the sensible horizon, which ought to be clear and well defined, is waved like a field of corn in the wind, or the surface of the sea in a storm.

So

So long as this diurnal tumult is kept up, the vapours stay in the air; but when it subsides, and the sun departs, they are condensed, and fall down to the earth in the night, as dew. It is very common in an evening to see a white mist creeping over the meadows near a river. The water of a river, which was warmed in the day, frequently continues so warm in the night, that the evaporation is still carried on; while the adjacent air, being colder than the water, condenses it as it rises, and it spreads in the form of a white mist over the neighbouring grounds, to be dissipated and carried aloft by the sun of the succeeding day, when the tumult commences as before described.

These nocturnal mists are most common at that time of the year when the twilight shortens very fast, on account of the more perpendicular descent of the sun below the horizon, that is, about the autumnal equinox. It is also probable, that at this season the body of the earth retains much of the heat which it acquired in the course of the summer, and that the exhalations from the earth may be more copious on this account. But the sun being now weaker, the dews lie long upon the ground; sometimes during the whole

day. The heads of mountains being colder than the lower grounds, the vapours that float in the air are there condensed, so as frequently to cover them with what seems to be a cloud at a distance, but it is a thick mist to those who are in it.

Cause of Rain inquired into.

When a mist is raised to a certain height in the air, it becomes a cloud; and is either at rest in the atmosphere, or carried about by the wind, till it falls in rain, hail, or snow. It seems more easy to account for the falling of vapours from the air, than for their ascent from the earth; but we shall find an unexpected difficulty. The common solution is this: that the air sustains the cloud, so long as the air and the cloud are of the same specific gravity; but when the air becomes lighter, it lets the vapours fall downwards. This is exemplified to the sight by an elegant and easy experiment with the air-pump. The air is always charged more or less with moisture; and when a clean glass receiver is taken, and a part of the air withdrawn, the vapour, which before was invisible, is detached from the air, and falls towards the bottom of the glass in the form of

of a fine drizzling rain. Since the use of the barometer, which measures the pressure of the atmosphere, we find by observation that the weight is generally less before rain, and that it increases again when the weather is like to be fair; whence the rising and sinking of the barometer afford us a mechanical rule by which we judge of the weather, independent of all other appearances.

The pressure of the atmosphere may be lessened on several different principles; either by rarefaction, dissipation, or an absolute loss of substance. Cold and heat have an immediate effect in contracting or expanding the air. At the equatorial parts of the earth, where the air is constantly in a more rarefied state, the barometer always stands lower than with us, and nearer to the pole it stands higher: so that cold and heat may well be supposed to change the density of the air in such a degree as to affect its pressure on the barometer.

The air may also become lighter, by means of a current of wind setting out from the place of observation, and exhausting, as it were, to a certain degree, the neighbouring region of atmosphere; especially if it should so happen that the wind should be going off

from the place in question in contrary directions at the same time.

Experiment hath taught us, that the air is also subject to a loss of substance; that is, that there are certain bodies, such as fire, saline vapours, and mineral exhalations, which actually work upon its substance, so as to leave less air in a given space than there was before: as on the contrary, the quantity of air next the earth is frequently increased, and consequently condensed, by large supplies from the pores, crannies, and caverns of the earth itself: of which more in another place. The body of the earth has certainly a very great share in changing the condition of the atmosphere, by sending up at some times a warm rarefied spirit, at other times a permanent regenerated air. In some places the earth emits mineral steams which will take fire at a candle. In thousands of other places there may be kindred exhalations, which being of an inferior kind, and short of inflammability, are not observed by us: but they must have a considerable effect on the temper of the atmosphere.

Wonderful Suspension of the Clouds.

The learned Dr. Wallis was of opinion, that unless

unless we suppose the air much affected by the body of the earth, the comparative gravity of air and vapour will yield us but a lame account of the weather*. Whoever considers this matter will be convinced that comparative gravity will never be sufficient to solve the phænomena of the vapours in the atmosphere. I hinted at this difficulty above, but did not then explain it. It seems an unquestionable fact, that clouds loaded with an immense quantity of water, which bulk for bulk are much heavier than the circumambient air, are suspended without any apparent difficulty, and transported over vast tracts of the earth. Here we must call in another principle; and we cannot be long to seek, when we have now in the electric fire a cause adequate to every appearance. This fluid passes from the earth to the clouds, from the clouds to the earth, and from one stratum of clouds to another. When any two of these have more than their due proportion, they are parted farther asunder: when they are unequally charged, they approach nearer together till the equilibrium is restored. This is

* See an excellent Discourse on the Changes of the Weather, by Dr. Wallis, in the Abridgement of the Phil. Trans. by Lowthorp. Vol. II. page 122, &c.

is most remarkable in a thunder storm, when the most bulky clouds are suspended in the air, till they part with some of their fire in lightning; at which time they collapse into a still denser form, and fall hastily to the ground in large heavy drops of water, bringing down with them more of that fire which is wanting to restore the equilibrum below. What happens suddenly, and with a shock, in thunder storms, is, on other occasions, brought to pass by a more silent and imperceptible translation of the ethereal fire from the heaven to the earth, by the mediation of a falling cloud. How is it possible to conceive, that clouds condensed into snow should be supported in the tracts of air that lie above the Alps, on the principle of comparative gravity? They seem there to be as high over head as in other places, though the barometer at that elevation would fail four inches of its usual height at the level of the sea. If snow falls with us, because the mercurial column is shortened to 29 inches, how can it be supported in the air, where the column is less than 26 inches? Here gravity will do nothing; and we must be obliged to assign some better reason for the suspension of the clouds. It is so easy and familiar to us to

compare

compare things by that common criterion of their weight, that we are apt to have recourse to it upon all occasions. This difficulty increases upon us, when we reflect that the superior air of the Alpine regions is so much colder as well as lighter than the air at the level of the sea; on which account the vapours must be more condensed there than in the lower parts of the atmosphere. Indeed, the air of that region, where the walk of the clouds is in that mountainous country, is so cold as to freeze all the vapours that ascend into it, even in the summer-time. Our learned naturalist, Mr. Ray, was so much struck with the contemplation of this strange fact, that his words upon the occasion are very remarkable: "We see that in the height "and heat of summer, in great thunder-"storms, for the most part it hails: nay, "in such tempests, I have seen mighty "showers of great hailstones fall, some as "big as nutmegs or pigeons eggs; and in "some places such heaps of them as would "load dung-carts, and have not been dis-"solved in a day or two. At the same sea-"sons, I have observed in some showers hail-"stones fall of irregular figures, and through-"out pellucid like great pieces of ice, with

"several

"several snags or fangs issuing out of them: "which, how they could be supported in the "air till they amounted to that bulk and "weight, is a thing worthy to be more "curiously considered. For, either they "must fall from an incredible height, the "vapours by the way condensing, and as it "were crystallizing upon them into ice, and "in time augmenting them to that bulk; or "else there must be some strange and un-"known faculty in the air to sustain them*." And so I think we are obliged to confess, that there is a faculty, then unknown, in the elements of air and fire, which has no dependence on the comparative gravity of fluids; and without such a faculty we cannot account for the motions of clouds and meteors. The treasures of snow and hail, &c. are amongst the secrets of nature, upon which we may meditate with wonder and pleasure, while at the same time we can never hope fully to explain them.

Snow.

When clouds of vapour are frozen into snow, the flakes generally take some regular figures, which always agree in this particular, that

* Ray's Three Discourses, page 101.

that they are hexagonal. Several of these are represented in the Phil. Trans. as they were observed at Middleburgh in Zeeland, by Dr. Stocks*. I have examined them myself in England, and always found the figures to be similar, though much diversified in their ramifications. In what manner they are disposed while they lie undisturbed in the cloud, it is not easy to imagine: but they are probably disposed in large sheets, or thin strata; because the hexagon is one of those figures, any number of which will apply to each other in the same surface without loss of room.

Hail.

Hail differs from snow in this respect, that it is not flat, but commonly spherical; and thence it is judged, that the water of a cloud is

* Abridg. Vol. VIII. page 506. Dr. Grew observed more particularly, that the flakes of snow are not only composed of stars of six points, but that "upon each of these "points are set other collateral points, and those always at "the same angles as are the main points themselves." He adds, "that not only some few parts of the snow, but ori"ginally the whole body of it, or of a snowy cloud, is an "infinite mass of icicles regularly figured; not one particle "thereof, not one of so many millions, being indeterminate "or irregular." Ibid. Vol. II. page 148.

is first formed into detached drops of rain, which falling through a colder region of the air, are there congealed in their passage into a rarefied sort of ice, not unlike to a compressed snow-ball*.

Frost.

Frost for the most part happens with an air perfectly serene; and the reason of it may be this: that the atmosphere then receiving no supply of warm vapours from the earth beneath, the frosty coldness of the upper region takes place upon it, and reduces it to its own temperature; for I suppose that to be the proper region of cold. And it is observable, that though a thaw sometimes is brought

* It is worth a critical remark, that the original word in the Scripture which denotes *hail*, signifies by analysis (a method which must sometimes be admitted) *in descensu*; expressing the peculiar circumstance which is supposed to attend the formation of it. Dr. Halley gives an account of hailstones, some of which weighed five ounces each. A common hen's egg does not weigh quite two ounces. He adds this remark, "it was most extraordinary, that such "sort of vapours should continue undispersed for so long a "tract as above sixty miles together, and in all the way "of its passage occasion so extraordinary a coagulation and "congelation of the watery clouds, as to increase the hail-"stones to so vast a bulk in so short a space as that of their "fall." Ibid. page 145.

brought on by a warm southerly wind, and so is derived from the air, yet it frequently happens that the progress of a thaw is from the ground upwards, the departure of a frost being in this case owing to a warm vapour or mist arising from the bowels of the earth. I have seen the branches of the trees still covered thick with the hoar-frost, tender as it is, while the ground below has been thawed. It is reported by those who have passed the Alps in the dangerous season, that the vast heaps of snow begin in some places to decay from the ground upwards, till there is a concavity underneath, and nothing but a shell or crust, of a monstrous size, left at the surface, supporting itself upon the craigs and shelves of the mountain, so that travellers pass underneath it. These tremendous vaults of snow hanging over head, are at length so tender, and rest on such a small foundation, that they use the precaution of taking the bells from their mules, lest the vibration of the air should make the snow break from its lodgment and overwhelm the traveller with its ruins.

Thunder Storms.

The phænomena of thunder and lightning are referred by all modern philosophers to the

the heaven and the earth, gives birth to many appearances which were formerly not so well understood. In a storm of thunder we see the fire returning from the air to the earth with a violent shock and an explosive noise: in the Aurora Borealis we see the same fire going off by a silent transpiration from a dark cloud in the horizon to the higher regions of the air; the cloud, in this case, being probably impregnated by the earth below for the supply of the heaven above.

I must beg leave here to introduce some articles of meteorological history, for the illustration of what I have to say upon this part of the subject. On occasion of an Aurora Borealis, on April 9, 1776, I noted that wherever the flashing appeared, it arose, as it usually does, out of a black cloud; and as the clouds were distributed about the sky in scattered fragments, they all seemed as so many roots or sources of fire darting upwards from each of them. These clouds wasted apace, and as they grew fainter the flashing abated. When they were gone, the flashing that remained seemed to arise from other clouds more remote and nearer to the horizon. Some of the clouds, from whence the fire seemed thus to evaporate, appeared above

above 45 degrees high. From many other like observations, I consider the Aurora Borealis as a more dilute sort of lightning, owing to a state of the air contrary to that which produces the common lightning which strikes downward to the earth.

Once or twice I have observed a meteor, which seems to be of a middle nature between the Aurora and the thunder-storm, flashing like lightning, but without any noise, and proceeding from clouds which were very thin and nearly in the zenith. On the 8th of July 1769, when the two preceding days had been very hot and sultry, the sky, about ten o'clock at night, was overspread with clouds resembling that dusky vapour in the horizon from whence the Aurora Borealis proceeds. The body of them was black and lowring; but their skirts, which spread over a large tract of the heavens, were unnaturally white, and so thin that the stars appeared through them. In these there was a slight undulation, and the figure of the clouds changed every minute, though no wind was stirring. All these circumstances convinced me that the phænomenon was to be referred to the Aurora Borealis: but what surprised me very much was the frequent

appearance of vivid lightning, sometimes in the zenith, sometimes in the horizon or near it, but all without any noise of thunder. This meteor seemed to connect the phaenomenon of the Aurora with common lightning, and to shew that the matter of both is the the same.

Many years before, while I was at Oxford, I observed frequent flashes of a pale light nearly over my head in a dark tempestuous night. The sky was almost covered with thick clouds, and the wind very high, but there was neither thunder nor rain. The flashes above-mentioned never appeared but on the rising of a more violent gust of wind, and they had nothing of the vivid appearance of lightning, but were as dilute as the streaming of an Aurora; though they were instantaneous like lightning, and shewed themselves in every quarter of the sky, but chiefly in the south. We have no name for this meteor. It is a common observation, that no cloudy and moonless night which is very windy is ever very dark; as if the wind by its motion always raised a light in some degree, through the agitation of the elements, and the collision of the vapours that are floating in the air.

While we are considering these things, it ought not to be omitted, that actual thunder and lightning has been observed in those dense vapours and clouds of smoke which ascend from a burning mountain during the course of a violent eruption. The fire of the volcano impregnates its own vapours with that matter, which either shoots back to the earth from whence it came, or darts from one part of the vapour to another, with very loud peals of thunder. How dreadful must this spectacle be! the air thundering about and flashing with lightning, while the earth pours out flaming matter from beneath with an explosive noise more loud and penetrating than thunder itself! The fire of a volcano is what we call culinary fire, which being here productive of lightning, I do not see how we can avoid the conclusion, that culinary fire and lightning are the same element. If lightning will set wood on fire, and flaming fire will turn into lightning, they seem to be convertible terms.

Winds, Storms, and Hurricanes.

Storms and hurricanes are usually accounted for on the principle of an unequal distribution of heat in the air of the atmo-

sphere; and I have myself frequently observed, that a day in which the air hath been uncommonly hot and close for the season, has been succeeded by a violent storm of wind. When the air in any space is rarefied, the surrounding air, which is more dense, rushes in with violence to supply the vacuity. That which is most dense will be carried toward that which is most rare; and a very sudden rarefaction will produce a sudden current of wind. A draught of air is always perceptible from a cold closet into a room warmed by a fire, though the said closet has no communication with the outward air; and the current will continue so long as the difference is considerable between the two places *. We have therefore nothing to do, but to suppose the air of any place heated and rarefied, either by the reflexion of the sun's rays, or by the rising of subterraneous exhalations; and the consequence will be, that

* Pliny has the same observation—*In domibus etiam multis, manu facta inclusa opacitate conceptacula auras suas habent.* Nat. Hist. lib. ii. c. 45. His language is here very obscure; but he means to say, that as there are caverns under the earth, from whence a cold air issues toward the surface of the earth, so there are dark apartments in a house, with no inlet, out of which nevertheless a wind is observed to blow; and the case is very common.

that the air of a colder region will rush in with a degree of violence answerable to the rarefaction. But here, as our views are very partial, and we are always apt to derive that from one cause which ought to be ascribed to many, we find our theory perplexed by this observation, that the highest winds and storms in this part of the world blow from a warmer country to a colder. When the air of Britain is rarefied, the supply ought to be derived from Norway, Denmark, Muscovy, and the Alps: but our storms generally come from the south-west, and consequently blow to the north-east; that is, they go to the countries from whence they ought to come. We bring ourselves into this difficulty, by imagining there is no commotion in the atmosphere till the colder air rushes toward that which is warmer: but ought not the very extension of the air by heat to produce a wind of itself? If the air from the poles goes toward the equator because it is colder, will not the air from the equator go toward the poles when it is expanded by the sun's heat? Where else can it go? not toward the sun, for the sun repels it; it will therefore be driven toward the poles, and will take an oblique direction in that course where it

meets with least resistance. According to circumstances, sometimes the polar, and sometimes the equatorial current will prevail.

Winds from subterraneous Causes.

Besides the effects of those causes which act upon the earth, there is undoubtedly either a generation, or at least a derivation of wind, from the internal body of the earth and sea, and that in immense quantities, and sometimes with great violence. If this happens to be attended with an unusual degree of the solar, and a concurrence of the subterraneous heat, the effect will be very great; because the air, in such a case, is both accumulated and expanded at the same time.

Lord Bacon, in his *Historia Ventorum*, has a title which he calls *Origines Locales Ventorum*, under which he reckons three sources of the winds; one, by descent from the upper region; another, from the expansion of the lower air; and a third, by exspiration from the earth; of which last he proposes it to be inquired, what winds blow out of subterraneous caverns; whether they come forth in a large body, or blow insensibly here and there, and unite afterwards into one

stream, like a river formed out of many different springs?

Many are the accounts (I wish we had a good collection of them) of winds derived from the subterraneous parts, and issuing either from the caverns, the fissures, or the pores of the earth, and producing storms and hurricanes. The earth has such crannies or fissures in all parts of it, from whence occasional supplies may be derived to the atmosphere, sometimes sensibly and violently, at other times imperceptibly, according to the state of things above and below; and this reciprocation between the earth and the air is a very interesting part of natural philosophy. In the language of Holy Writ, God is said to *bring the winds out of his treasures;* as if some hidden promptuary or store-house were alluded to, such as that of the waters and cavities beneath the earth. The heathen philosophers and poets, in their mythological way of expressing the operations of nature, describe their deity Æolus as presiding over winds pent up in caverns of the earth; to which Ovid, alluding in his Cosmogony, says,

> *Protinus Æoliis Aquilonem claudit in antris.*
>
> Metam. Lib. I.

That of Virgil, in the first book of his Æneid, is to the same purpose:

> *Sed Pater Omnipotens speluncis abdidit atris,*
> *————— molemque et montes insuper altos*
> *Imposuit —————*

According to the traditional philosophy of that age, which is verified by modern observations, it was believed that winds were derived from beneath the earth, and that even some of the most violent storms could be accounted for only on that principle.

Philosophers, who speculate in their closets, treat the notion of subterraneous winds with contempt, as nothing more than a fable of the heathen poets, whose representation, though fabulous, is yet built upon the real history of nature, and confirmed by many accounts, both ancient and modern, of which I shall here produce a specimen. This subject was slightly mentioned in the Discourse on Air, (see Vol. ix. p. 424, 425.) and Justin's description of the chasm in the rock at Delphi was alluded to in the mythological part of the same Discourse, (*ibid.* p. 497, 498.) Pliny agrees with Justin in affirming, that a cold wind continually issued from that chasm, and the situation was certainly preferred as the

the fittest for an oracular temple, on account of this subterraneous air.

In a pit of Sir J. Lowther, at Whitehaven in Cumberland, when the workmen first pricked a black stone bed, which was on the rising side of the pit, it afforded very little water, contrary to what was expected; but instead thereof, a vast quantity of damp corrupted air, which bubbled through a quantity of water, then spread over that part of the pit, and made a great hissing noise. This air was afterwards directed by a pipe to the mouth of the pit, and its blast continued undiminished for several years: it was very cold; and from the minerals through which it passed, it had contracted an inflammable quality, so that it would take fire at a candle. It had no bad effect upon the lungs of the workmen different from common air*. By accidents under ground, not known to us, vast quantities of such air may be detached suddenly, and occasion strange commotions in the atmosphere, perhaps in the body of the earth itself.

In the year 1768 the following account was dated from Waterford in Ireland, Sept. 5: "On Wednesday last a most violent tempest "happened

* Phil. Trans. Abr. Vol. viii. p. 656.

"happened in the neighbourhood of Three-"mile Bridge, near this city: it *arose out of* "*the quarries* in that place, and collected "itself into a body, so that nothing could "resist the violence of it." I set this down at the time, as the public papers then gave it; but have had no opportunity of inquiring more exactly into the particulars.

Sir W. Hamilton, in his curious relation of Mount Vesuvius, &c. has the following passage: " Near that part of the island called Lacco, there is a rock of an ancient lava, forming a small cavern, which is shut up with a door. This cavern is made use of to cool liquors and fruit, which it does in a short time as effectually as ice. Before the door was opened, I felt the cold to my legs very sensibly; but when it was opened, the cold rushed out so as to give me pain, and within the grotto it was intolerable. I was not sensible of wind attending this cold; though upon Mount Etna and Mount Vesuvius, where there are caverns of this kind, the cold is *evidently occasioned by a subterraneous wind:* the natives call such places *ventaroli,*" p. 153. If these are found in other mountains of the earth, there may be reason in Seneca's way of accounting for the Etesian, or annual

wind

wind of Greece, which he derives from the melting of the snows that had stopped the vents and caverns of a mountainous country*.

To the foregoing we may add an account of the winds from the mountain Biocova, in Primorie, on the coast of Dalmatia, by the Abbé Fortis. "From the mountain Biocova, as the Primorians say, proceed the winds, hail, rain, and every change of the weather: but their most accurate observations are those concerning the northerly winds; and they deserve to be inserted, because my late friend, Count Grubbisch, assured me he had found them by experience very exact. Before the north wind breaks out, if there is any fog upon the Biocova, it is raised on high, and scattered a thousand ways; a roaring noise is heard within the mountain, which soon becomes dreadfully loud, and the air grows sharp. The shepherds say, and it seems demonstrated by fact, that this wind comes out of the gulphs and chasms of the mountain. It is certain that it descends from the summit toward the sea like an impetuous torrent. When a good deal of rain falls on the mountain, there is no *Borea* (north wind); or if it begins

* *Item terras exoneratas nive refectasque spirare liberius.* Nat. Quæst. lib. v. c. 10.

begins to blow, it increases in violence only as the mountain becomes dry. But if after a long drought there falls a little rain, then the *Borea* usually blows; or when that does not happen, it is a sign that a south wind is near.—This wind usually begins to blow when the sun and moon rise or set *.

The *Cryptæ Æoliæ*, or wind-caverns, so frequent in Switzerland and elsewhere, have been described by many writers, particularly by some who are cited in Scheuchzer's *Iter Alpinum*; of which the following is an extract from a letter of Jacobus Piceninus to the author: *Ex Cryptis et hiatibus montium, ubique expirant venti. Id experimur in cellis vinariis frigidioribus (Italice,* Grotti) *in quibus si appendatur charta vel folium, mirum in modum ab expirante vento agitatur.—In extruendis Cellis hisce vinariis, magna requiritur Architecti industria ad invenienda non ubivis obvia* SPIRACULA, *quorum in una cella, unum, duo, tria, rarius plura reperiuntur* †. In English thus: "Winds blow out of the earth in all places from the cracks and caverns of mountains. We have experience of this in those wine-cellars which the Italians call

* Travels into Dalmatia, p. 275.

† Iter Alp. sec. p. 82.

call *Grottos*, where, if a piece of paper, or a leaf, be suspended by a thread, it is driven different ways by the wind. In the building of these cellars, it requires great industry in the architect to hit upon the vents, which are not every where to be met with, and of which there are seldom more than three found in the same cellar." The author tells us, that not only the thermometer was much affected with the cold, but that even the barometer was seen to rise a scruple and half of his measure with the difference of the air.

Another remarkable instance of the same kind is given us by Mr. Brydone, in his Travels into Sicily. "Betwixt this place (Giardini) and Messina, a little to the right, lie the mountains formerly called the Nebrodes, and likewise the mountain of Neptune, which is the highest in that chain. It is celebrated for a gulph or crater on its summit, from whence, at particular times, there issues an exceeding cold wind, with such violence that it is difficult to approach it. It is said to be so high, that the Adriatic may be seen from its summit. From the description they give of it, it appears evidently to be an old volcano."

cano."* It is no uncommon thing with the poets to derive storms from high mountains; like that of Homer,

——————— επι δε Ζευς τερπικεραυνος
Ωρσεν απ' Ιδαιων ορεων ανεμοιο θυελλαν. Il. μ. 253.

Jove breathes a whirlwind from the hills of Ide,
And drifts of dust the clouded navy hide. Pope.

When this really happens, and certainly the fact is more common in Greece and Italy than with us, it must be imputed in many instances to a derivation of subterraneous wind from the internal parts of the mountain; which wind being denser than that at the head of the mountain, mixes violently with it, till an alteration of the temperature below, or an accumulation above, forces it downwards, and then it seems to come as a storm from the mountains. The violent winds that are generally stirring at the top of all very high mountains, and which were spoken of in Vol. ix. p. 459, as very hard to be accounted for, will seem less strange when the internal source of the winds is considered and allowed for.

Winds from the Clouds.

There is another cause of winds and storms which

* See Vol. I. p. 103.

which is more open to common observation. Many of them are certainly derived from the quality of the clouds and vapours that are floating in the sky: and this may give us one reason why the most violent winds come to us from the south and west, because the clouds most commonly visit us from that quarter; while it is remarked, on the contrary, that the north wind dispels the vapours, and produces a serene air: *Ventorum frigidissimi sunt, quos e septentrione diximus spirare—ii et reliquos compescunt et nubes abigunt**. Virgil and Ovid express the same sentiment:

> —*nimbisque Aquilone remotis.* Ovid. Met. I. 323.
>
> —*Claro* sylvas cernes *Aquilone* moveri. Georg. I. 459.

And the like effect is attributed to it in the Book of *Job*, where it is remarked, that *fair weather cometh out of the North*†. I have myself observed, in a season of storms and showers, that a cold heavy cloud passing over head, with an hasty fall of snow or hail, has been attended with a sudden violent gust of wind, such as the seamen term *a squall*, which has subsided into a calm with the departure of the cloud, till another coming in the same direction has brought its blast with it;

* Plin. lib. ii. c. 47.   † Chap. xxxvii. ver. 22.

it; and this I have been witness to many times successively in the same day, and even for several days together. Much of the disturbance there is in the atmosphere is brought on by the clouds that arise and pass about in it; of which the Greeks were so well satisfied, that their word *Ecnephias*, which upon Pliny's authority signifies *a hurricane*, is, by interpretation, *out of a cloud.* No tempest, hurricane, or whirlwind, ever happens under a cloudless sky; and, generally speaking, the colder and denser the cloud is, the more violent is the blast.

If authors are to be credited, there is a sort of clouds and vapours in other climates, of which we have little conception in this country. Dr. Mather, speaking of the storms of New-England, gives us the following account: "Though they have not those hurricanes to which the Caribbee Islands are subject, yet they have had whirlwinds or gusts drive along a particular narrow tract for divers miles together, with a violence not to be opposed by any thing on earth; that if their towns had stood in the way, they must undoubtedly have been destroyed. Of these, a thick, dark, small cloud has arose, with a pillar of light in it, of about eight or ten feet

diameter, and passed along the ground in a track not wider than a street, horribly tearing up trees by the roots, blowing them up in the air like feathers, and throwing up stones of a great weight to a considerable height in the air, throwing down all in its passage: the noise this cloud made was so great all the while, that the noise of the mischiefs done by it was thereby quite drowned*."

Causes of Rain and Storms, by Boerhaave and Woodward.

Two eminent naturalists and philosophers, to whom the world is under many obligations, derive the greatest phænomena of the atmosphere from two different causes, both of which should have their share, though I apprehend neither of them ought to engross the whole subject. Boerhaave contends, that all storms are immediately occasioned by a reverberation of the sun-beams from the clouds. Woodward supposes all the changes of the weather to depend on vapours rising into the atmosphere from the waters of the great abyss under the earth, and that there is a constant correspondence betwixt this and the atmosphere. "I have long been of opi-

* Phil. Trans. Abr. vol. v. p. 110.

" nion (says Boerhaave) that the sun's light
" being repelled from icy clouds, and col-
" lected into vast focuses, was the chief
" cause of the many stupendous and de-
" structive effects from time to time ob-
" served in the atmosphere.—Hence light-
" ning, thunder, whirlwinds, storms, winds,
" and other meteors. Hence also we may
" probably conceive, why these rarely hap-
" pen in a hot season, if the sky is clear and
" free from clouds; and why, after the
" formation of clouds, such surprising
" changes so suddenly follow. More fre-
" quent and violent effects of this kind ne-
" ver happen than when after a long sharp
" frost, which has bound up the rivers, and
" even penetrated the earth's surface for a
" considerable depth: for if a sudden thaw
" then takes place, it is usually quickly suc-
" ceeded by a multitude of clouds, uncom-
" mon heats, and then by thunder and
" lightning. The reason is, that the va-
" pours and exhalations raised by the sub-
" terraneous heat, have long remained im-
" prisoned under that covering of the earth;
" as appears hence, that if the ice of a ditch
" be broke in the middle of a severe frost, it
" presently emits warm vapours, and this
" the

"the more plentifully, as well as the hotter, "by how much the frost is harder and the "ice thicker. As soon therefore as the ex- "terior frozen turf of earth is softened by "warmth, the pent-up vapours immediately "escape through all the passages they can "find, and mounting on high form clouds, "which being driven about, and sometimes "illumined by the sun, produce those ef- "fects above described. Hence those violent "thunders in Muscovy, Sweden, and Den- "mark, after a thaw*."

Dr. Woodward, so famous once for his Physical Geography, or Natural History of the Earth, imputes every thing in the atmosphere to the vapours that rise into it from the great abyss of waters under the earth. He

 contends,

* Boerh. Chym. by Shaw. Vol. I. p. 271, &c. All authors, ancient and modern, who have observed nature with any attention, agree, that there are certain phænomena which demonstrate that vapours are raised by heat within the body of the earth.

Videmus recenti fossione
——— terram fumare calentem.

Atque etiam ex puteis jugibus aquam calidam trahi, et id maxime fieri temporibus hybernis, quod vis magna caloris terræ contineatur cavernis, eaque hyeme sit densior; ob eandem causam calorem insitum in terris contineat arctius.

Cic. de Nat. Deor. lib. ii.

contends, that, on the common principles, it is a paradox that a pure air should raise the mercury in the barometer, while a foggy, or moist air, which is certainly heavier in itself, should let it sink. Water is a thousand times heavier than air; whence he argues, that, by the laws of hydrostatics, water and air must be heavier than air alone: how then can a damp foggy air appear lighter upon the barometer? To solve this difficulty, he supposes, that while the air is thus moist, the vapours from the earth are in a rising state, in a direction contrary to gravity; and that they then interrupt, bear up, and take off the weight of the atmospherical column: that, farther, it is impossible the watery and other vapours should ascend through the intervals of the aerial corpuscles without hitting and striking against them; whence it must follow, that, by their counter-impulse, the pressure or weight of the air must be diminished. For the effect of its pressure must not be estimated from the quantity of matter in the atmosphere, but from the direction or tendency of it. On this consideration, he thinks the atmosphere never presses with its full weight, because it is always interrupted in some degree by a counter impulse of vapour ascend-

ing

ing from the earth. In frosty and cold weather, the mercury is generally high, because the pores of the earth are closed, and the vapours intercepted. He argues, from the phænomena observable in mines, and places at great depth in the earth, that a great diversity of principles are dispatched out of the earth into the air against rain and storms; that a heat and damp under ground in mines is soon followed by a thick misty foggy air above: that mineral steams thus ascending to the surface of the earth, and being furthered by the heat there in summer and warm weather, mount up into the atmosphere, and contribute to the phænomena of thunder and lightning: that some steams are noxious and injurious to health, fevers being most rife in hot weather and the rainy seasons: that the rising of this vapour is evident to the sight from that tremulous motion of the atmosphere, in which an extremely fine matter is agitated and in continual undulation, much after the manner of a very thin ethereal lambent flame; which, doubtless, is no other than heat, or the subterranean fire, detached forth in small parcels, bearing up along with it fumes and steams, which are made the more visible by their agitations, and their

variously reflecting the light of the sun. And as the sun's power to act upon any part of the earth increases continually as it approaches the meridian; this assigns a cause for the rising of these kind of vapours chiefly about the middle of the day.

That the subterranean vapours arise from some vast reservoir, such as that of a great abyss of waters, he argues from the extensive effects of them; barometers in countries very distant having been found, especially upon all great extensive and lasting rains, to keep time, rising and falling nearly together, as at Upminster in England, observed by Dr. Derham; and at Zurick in Switzerland, observed by Scheuchzer. High mountains, that are very remote, appear capped with fogs in concert. Volcanos in distant regions have been observed to correspond exactly in their eruptions; as that of Vesuvius in Italy, and of Mount Semus in Ethiopia. But, above all, the shocks of an earthquake shew that there is some cause of commotions under the earth, which is almost as extensive as the earth itself, these being felt in several countries, and those the most remote, nearly at the same instant of time. The symptoms which attend earthquakes and volcanos shew that watery steams and

and vapours have as great a share in them as in the common disturbances of the atmosphere; on which consideration they may all be referred to the same cause. Earthquakes happen, either after a great drought, when the subterranean vapours have been long obstructed, or amidst great rains, when they are detached in too great abundance. They are sometimes preceded by hurricanes, and attended with a prodigious fall of the barometer *. The waters of baths are then hotter than usual; and all things conspire to prove that there is one universal source of great extent, which contributes to earthquakes, volcanos, fogs, damps, rains, winds, and storms; and that this can be no other than an immense body of waters under the earth. As the heat of the earth and the abyss happens to be restrained or dispensed forth, the atmosphere is pure and free, or charged with heat, extraordinary vapours, exhalations of all kinds, and humidity. Under the greatest restraint of it frost ensues; but as the heat of

* When the barometer had fallen to the cypher on Nov. 22, 1768, a letter which I received in the January after, from the late Sir John Hill, informed me that Haller observed the same in Switzerland, and had assured him that it was attended with an earthquake.

of the abyss begins to re-ascend to the surface, a thaw commences, and happens first in the parts nearest the earth; which shews that the principle resides within it *.

That warm vapours do ascend from the earth on some principle which does not appear to have any immediate dependence on the sun or the season, is plain from many observations, particularly this, that a sultry unseasonable air, at a cold time of the year, is suddenly felt without any motion of the wind. In such a case, whence can it be derived? It cannot be said that the heat is blown to us from some warmer country; for there is no wind to bring it: neither can it be supposed to descend to us from above; for then it would be cold instead of hot: it remains, therefore, that it must have transpired to us from the earth itself. Many observations have fallen in since Dr. Woodward's time, which agree well with his speculations, and indicate a very particular relation between rains and earthquakes. The earthquake at Lisbon, Nov. 1755, was succeeded by a winter of much rain and continual floods, one of them the

* See Dr. Woodward's Letters to Sir Robert Southwell, in the Introduction to his Illustration and Defence of the Natural History of the Earth, against Camerarius.

the largest that had been seen for twenty years: and the summer that followed was the wettest in the memory of man. In 1763 there was a dreadful earthquake at Comorra in Hungary. The summer and winter of 1762 were remarkable droughty; but the summer of 1763 was the wettest since the earthquake of Lisbon, and the succeeding winter was more rainy than the summer; the rains being by report common to the whole world, but greatest in Europe. According to Dr. Woodward's theory, it is most natural that a drought should precede an earthquake, and that rains and storms should follow. "It is the common received opinion (says Sir William Hamilton) at Naples, and from my own observation, is, I believe, well founded, that when Vesuvius grumbles, bad weather is at hand *."

The Sun and Moon are Causes of the Weather.

The cause which Dr. Woodward assigned for the changes of the weather is of such a nature, that we can reduce its influence to no rule, for we are entirely ignorant of the laws by which it acts. Other causes whereby the weather is affected are better known, and more

* See his Observations on Vesuvius, &c. p. 2.

more open to observation; and among these the first place is due to the sun and moon. The difference which universally obtains between the summer and the winter is owing entirely to the sun. When his heat is more powerful, the pores of the earth are more open, and vapours are raised in greater abundance from seas and rivers; consequently there is more rain in summer than in winter, and what happens is more violent. When the beams of the sun are suddenly withdrawn as in a solar eclipse, we learn what effect his rays had upon the atmosphere. I have seen the morning fine, clear, and transparent, till, as the moon came forward upon the sun's disk, the sky soon grew turbid, and overcast with vapours of a grey or livid hue, which retained their complexion for many hours after the eclipse was over. While the light of the sun was uninterrupted, the vapours were in a state of perfect solution and suspension; but when the cold intervened, a precipitation took place in the sky, as a sediment is deposited by a liquor under the like circumstances. The eclipse I allude to was that of April 1, 1764, but Dr. Woodward had observed the same on occasion

occasion of the total eclipse in the year 1715 *.

At the time of the equinoxes, when the sun passes from one hemisphere into the other, there is almost constantly some disturbance in the weather; the winds are then generally higher: at the vernal equinox they are for the most part easterly, and withal cold, dry, and searching. The solstitial point of the summer is more apt to be distinguised by violent rains, and what we call a midsummer flood. The winter being less rainy than the summer, nothing particular happens at the winter solstice, but that the frosts commonly set in more severely, with some quantity of snow, which lies long upon the ground.

The sun is the undoubted cause of the sea and land breezes. These are wisely appointed by Providence to make the hotter climates habitable. The sea-breeze in the West-Indies begins to appear about nine o'clock in the morning, in a fine black curl upon the water approaching the shore; it increases gradually till noon, and dies away at four or five in the afternoon. About six in the evening it changes to a land-breeze, which blows from the

* See Nat. Hist. of the Earth illustr. p. 137.

the land to the sea, and lasts till eight in the morning. There is an interval in the morning and evening between the changing of the breezes, when the wind is stationary like the water before the turning of the tide; and these intervals are the hottest parts of the day. These breezes are thus accounted for. When the sun is up, his heat takes effect on the land more than on the water, so that the heat is accumulated, and the air over the land is rarefied; and as it mounts upward, the colder air from the sea comes in to keep up the equilibrium. In the evening the dews are so excessive, and the cold so sudden upon the land, from the quick descent of the sun below the horizon, that the water in the night is warmer than the land, and the air of the sea being then most rarefied, the draught of air is contrary to what it was in the day.

Trade Winds and Monsoons accounted for from the Sun.

But the effect of the sun is no-where more conspicuous than in the phænomena of the trade winds and monsoons, which are so called, from the eminent service they are of to trade and navigation. The general theory of them, as laid down by several philosophers,

phers, but particularly by Dr. Halley, is this.

As the sun in his diurnal motion goes from east to west, the meridional point to which he is vertical is most heated: and as this point of greatest heat is continually shifting westward, a wind will follow it according to the law of statics; and consequently the diurnal motion of the sun must produce an easterly wind all round the globe, in those parts of it to which the sun is vertical; and the current being revived as fast as it decays by the daily return of the sun to the meridian, it is made perpetual. On the same principle it follows, that as the air will be most rarefied in the parts nearest the line, the air on the north side of the equator, being cooler, will flow in, and change this east wind into a north-east; and for the same reason the air on the other side from the southern tropic will change it into a south-east. These two currents from the tropics, compounded with the former general easterly wind, will answer all the phænomena of the general trade winds; and if the whole surface of the globe were sea, they would be uninterrupted, as in the Atlantic and Ethiopic oceans. But as the continuity of the ocean is broken by the inter-

position of great continents, regard must be had to the interruption occasioned by the nature and quality of the land; which introduces such a variety of cases, as it would be an endless task to state and explain particularly. Thus, for example, the inland sandy deserts of Africa being violently heated by the sun, the wind on the coast of Guinea always sets in upon the land, blowing westerly instead of easterly.

But now farther; as the cooler and denser air presses toward the equinoctial, and is there rarefied, it must mount upwards, and produce another current aloft in a contrary direction: so, by a circulation which must necessarily happen, the north-east trade wind below will be attended with a south-west wind above. The limits of the trade winds extend to thirty degrees on each side the equator; and when we are without these limits, it is usual to find a wind in a direction contrary to the trade wind. From the upper current, and circulation above-mentioned, the monsoons in the Indian ocean are accounted for, which blow six months one way, and six months the contrary way. Northwards of this ocean, there is land every-where within the limits of thirty degrees; and in April, when

when the sun begins to warm those countries to the north, the south-west monsoon sets in, and blows during the heats till October; when, as the sun retires, and the heat increases to the southward, the north-east winds enter, and blow all the winter till April again. If we were to pursue this subject, the case is very complicated, and there are some difficulties which perplex the scheme too hard to be well cleared up. Practical navigators lay no great stress upon such theories, and even deride the speculations of philosophers, because there are in nature deviations from the general rule: but as this will be the case more or less with all human theories, speculation ought not upon that account to be depreciated and laid aside: and, in the present case, the general principle is well established, and agreeable to the soundest rules of philosophy.

It is reasonable to believe, that the upper current occasioned by the trade winds, when it comes beyond the tropical limits, should descend towards the earth, and that it may probably extend even to the higher latitudes, and account for those south-westerly winds which prevail so much in these parts of the globe: which is also the opinion of Mr. Hadley, who

who attempted to improve upon the theory of Dr. Halley *. He lays it down, as before, that the rarefaction at the equator must occasion an in-draught of the air from the tropics; but accounts for its oblique direction as an easterly wind, from the greater velocity of the earth in its diurnal motion at the equator; which occasions the air in its motion from the tropics to be left behind, and meet the equator more to the westward, which will give it the appearance of an east wind. This is very subtile and ingenious; but I apprehend the trade wind is too much of an east wind, even beyond the limits of the tropics, to be accounted for on this principle.

The Moon.

Another very considerable cause which has much influence on the weather is the moon; and that it actually has such an influence, I have long been convinced both by reason and experience. For, first, as to the reason of the thing, it would surely be unphilosophical to imagine that the moon, which has so manifest an effect every day upon the tides of the sea, and is allowed to have it by all writers, ancient and modern, should have no effect

* Trans. Abr. vol. viii. p. 500.

effect at all upon the body of the earth, and the vapours that surround it, giving them no kind of fluctuation, though the vapours in the air are as moveable as the waters of the sea. To say that the moon raises tides in the air similar to those in the sea, is too much, because we have not the evidence of it, which we certainly should have if it were true. But that the weather, as to foul and fair, is affected by the moon, no person of any observation can possibly doubt. We may frequently see a course of weather, which has lasted for two or three or even four months together, all break up and go off at the change of a succeeding moon. But here it is to be noted, that as the highest tides are not immediately at the change, but four or five days after, so those days are for the most part an index to the weather of the month, and if there is to be rain, it most frequently commences at that time. Very often I have seen the weather alter suddenly on the very day of the change, and sometimes near to the hour itself. Even the returns of the moon to the meridian, as well as her monthly motion, are thought to have their effect. Once at a sea-port, on a very rainy day, I inquired of a person what he thought of the weather?

He answered me, that it would clear up at the time of high water, as, he assured me, he had commonly observed for many years; and, unpromising as the sky seemed at the time, his prediction was then verified; the sun shone out at the proper time, and the day was fine afterwards. A gentleman, who had many times crossed the line and the polar circles, and made his observations many years in the hottest and coldest climates of the earth, gave me this rule, which frequent experience, he said, had confirmed to him past all doubt; that these two days of the moon, on which the lowest neap tides fall, have the best chance to be fair against all the rest. My kind and learned friend, the late Granville Wheeler, esq. of Otterden-Place in Kent, who had applied himself for many years to mathematical and philosophical studies, informed me, he had long experienced, that even the distance of the moon from the earth had an effect upon the weather, and that therefore he was always attentive to the perigee and the apogee.

These rules, and all our rules, will fail occasionally; but this is no sufficient reason for disregarding them: they hold so often, at least with respect to the moon, that they have attracted

attracted the general notice of men in all ages. It was a vulgar opinion, confirmed by common observation, that the wind in Italy was generally more troublesome about the change of the moon; as we have it upon the authority of Horace, who alludes to it in his poetry:

Thracio bacchanti magis sub interlunia vento *.

Cleomedes, a Greek writer upon Meteorology, asserts the same in a more philosophical way, in his Second Book; adding, moreover, that the moon is the chief cause of the tides, and that her rays can never be made to burn by refraction, like those of the sun †.

 The

* The like observation was made by Captain Middleton in Hudson's Bay, that, "at almost every full and change of the moon, there are very hard gales from the North." He likewise found what he calls a northerly trade-wind near the Pole, and justly supposes it to have correspondence with the trade-winds in the torrid zone; it blows constantly for seven months, from October till the beginning of May. The same wind is found in Canada for five months, in Davis's Straits for seven months, and on the coast of Norway for five months and half.

† The passage I refer to in Cleomedes is worth our attention, and it is curious to see an ancient writer speaking with such extent and precision upon a physical subject. Η σεληνη, κατα τας των σχηματων διαφορας, ȣ μονον εν τω αερι μεγαλας εργαζομενη τροπας, και καταχραιȣσα αυτα, και

The scripture teaches us, that the sun and the moon were made for *Signs*. In what other sacred sense this may be understood, it would be out of our way at present to consider; but it is probably here suggested to us in a natural sense, that they foreshew us, by their motions, appearances, and places in the heavens, what is to be expected by sea and land in the course of the weather; a matter of so great importance to the necessary business and welfare of mankind, that

Divine

και μυρια επιτηδεια εργαζομενη, αλλα και των περι τον ωκεανον πλημμυριδων και αμπωτεων αυτη αιτια εστι· κακεινο δ' ετι προσεστιν οραν αυτης τη δυναμει, απο μεν γαρ τε παρ' ημιν πυρος, εκ ενεστι κατ' ανακλασιν πυρ· απο δε των ηλιακων ακτινων επιτεχνωμενοι λαμβανομεν πυρ κατ' ανακλασιν. "The moon, according to her different appearances, not only causes great revolutions in the air, over which it has the power, and produces many serviceable effects; but is also the cause of the flux and reflux of the sea. It is farther worth our while to observe, that, by the power of her rays when refracted, it is impossible to obtain such fire as ours; whereas, by the help of art, we can obtain fire from the rays of the sun by refraction." *Cleom. Theor. Meteor.* lib. ii.

Quid de fretis aut de marinis æstibus plura dicam? quorum accessus & recussus lunæ motu GUBERNANTUR. *Cic. de Divin.* lib. ii. cap. 14. Ea fuit sane multorum veterum sententia: Κατα γαρ της σεληνης αυξησεις και φθισεις αμπωτεις τε και πλημμυριδες περι τινα μερη της θαλασσης γινονται. *Sext. Empiric.* p. 93. Vid. *Cic. de Nat. Deor.* Davisii, 1733, p. 146.

Divine Providence may well be supposed to have given us proper signals in the heavens from the beginning of the world: and, without question, numberless are the instances in which multitudes of the human species have been lost by not attending to them.

The latitude of any place is the position of it in respect of the sun; and this may be taken as a general index to the temperature of the climate, and the weather that may be expected in it. This, however, is liable to great interruptions and exceptions, as we shall have occasion to explain particularly hereafter; but to deny it absolutely, would be to deny that the sun is a source of heat and light to the world below. In the regions within the arctic circle, such a severe coldness prevails, that the sea is loaded with islands of ice, which, perhaps, have been increasing ever since the time of the universal deluge; and the land is concealed in many parts under mountainous heaps of everlasting snow. Some of these islands of ice are immersed six hundred feet under the surface of the sea, and are extant more than an hundred feet above it, and are three or four miles in circumference. I cannot forbear to

exhibit, by the way, some of the scenery produced by the arctic weather, as it has been described to us by some modern voyagers.

At Smearingborough harbour, within fifteen degrees of the Pole, the country is full of mountains, precipices and rocks. Between these are hills of ice, generated, as it should seem, by the torrents that flow from the melting of the snow on the sides of those towering elevations; which being once congealed, are continually increased by the snow in winter, and the rain in summer, which often freezes as soon as it falls. By looking on these hills, a stranger may fancy a thousand different shapes of trees, castles, churches, ruins, ships, whales, monsters, and all the various forms that fill the universe. Of the ice-hills there are seven that are most remarkable; these are known by the name of the seven Ice-burgs, and are supposed the highest in the country. When the air is clear, and the sun shines full upon them, the prospect is inconceivably brilliant. The sun is reflected from them as from glass: sometimes they appear of a bright blue, like sapphire, and sometimes like the variable colours of the prism, exceeding, from the magnitude

magnitude of the lustre, the richest gems in the world, disposed in shapes wonderful to behold, all glittering with colours that dazzle the eye, and fill the air with astonishing brightness. At Spitsbergen, within ten degrees of the Pole, the earth is locked up in ice till the middle of May. In the beginning of July, the plants are in flower, and perfect their seeds in a month's time. The air about this place is never free from icicles. If you look through the sun beams transversely as you sit in the shade, instead of dark motes, as are seen here, you see myriads of shining particles that sparkle like diamonds; and when the sun shines hot, as it sometimes does, so as to melt the tar in the seams of the ships when they lie sheltering from the wind, these shining atoms melt away and descend like dew. When the sun is to the northward, it is possible to look at him with the naked eye, as at the moon, without being dazzled; because he is then seen through the dense icy atmosphere of the polar region.

If any register of the barometer has been made in this air so near to the Pole, I have not been so fortunate as to meet with it; neither do I meet with any accurate account of the horizontal refraction of the heavenly

bodies, though it must undoubtedly be very great in this icy medium. If what Gassendus, in his Astronomy, reports of those Dutchmen who wintered in Nova Zembla within fifteen degrees of the Pole be true, the sun, at his return in the spring, became visible to them seventeen days sooner than he ought to have done according to that latitude. The difference of the sun's declination for those seventeen days, as it has already been observed in a preceding discourse, will therefore be equal to his horizontal refraction, and it amounts to above four degrees, which is seven times as great as the horizontal refraction in the latitude of London.

One circumstance I cannot forbear to mention, that this land, under all the inclemency of its air, and locked up with frost in the winter to the depth of twelve feet, is inhabited by many deer. How to account for their subsistence, is one of the most difficult problems in natural history. Some think they retire in the winter to the northern continent: but it is too far off; and how are they to live by the way, in their journey over the ice, supposing it possible for them to perform it? This difficulty is as great as the other: yet it is a fact that they do subsist,

and

and Providence must have ordained some way which we do not understand. As the thing appears to us, they must unavoidably suffer a famine of eight months, without a bush to shelter them! No human creature can live there to trace them to their winter's residence; and so their subsistence must remain a secret to us for ever *.

Though the sun is so much more oblique in the higher latitudes than with us, and the effect of his rays weaker in a given time, his very long continuance above the horizon is attended with an accumulation of heat, so as to exceed the heat of many places under the torrid zone: and there is great reason to suppose, that the rays of the sun, at any given altitude, produce greater degrees of heat in the condensed air of the polar regions, than in the thinner air of this climate. Some experiments are wanting to illustrate this article of philosophy. Within fifteen degrees of the Pole, the air, heated by the sunshine, and sheltered from the north wind, was up to 90° of Fahrenheit's thermometer. At Petersburgh, in Russia, the summers are hot, and the corn is sown, ripened, and reaped, in

* See the Account of Captain Phipps's late Voyage to the Northern Seas.

in a much shorter space of time than in the latitude of London. In the Highlands of Scotland, the sun, in the middle of the summer, descends but little below the horizon; and I had it from an officer of the army, who was marching there on a summer's day with the same men whom he had commanded at Carthagena, that they all agreed they had never suffered so much from the heat in the West Indies, as on that day in the Highlands of Scotland. Their way might probably lie through some vallies between white rocks and cliffs, without any fresh air, and with intense heat from the reflection of the sun. Such, however, was the fact, whatever was the cause of it. This fact was mentioned before, and some observations made upon it in that part of the Discourse on fire which relates to the heat of climates. See p. 314. vol. ix.

On the other hand, the cold was found to be so severe in the winter of the year 1756, in the city of Dierbeker, on the borders of Persia, which is not quite fifteen degrees from the torrid zone, that the mercury of Fahrenheit was sunk into the ball, and the people died suddenly with cold in the street. This city is upon a hill, in the middle of a vast plain, which is surrounded with high

mountains to the north and east, on which there is perpetual ice and snow *. The upper region of the air is the natural repository of frost and snow, let the climate be what it will; and high mountains keep up such a communication with it, that its temperature is transferred by the winds so as to overcome all that might be expected from the proximity of the sun. Yet certainly, if we look for heat, and all the most remarkable effects of it, we must go to the countries near to the equator, where we shall find a sort of scenery totally different from that of the arctic circle. All things are upon a larger scale than in the temperate climates: their days are burning hot, their nights piercing cold in many places, their rains lasting and impetuous like torrents, their dews excessive, their thunder and lightning more frequent, terrible, and dangerous; and there are some phænomena with which, in these parts of the globe, we are very little acquainted—these are the tornado and the water-spout.

The Water-Spout.

The tornado is a sudden turning of the wind,

* See Ives's Voyages and Travels over Land from the East Indies.

wind, which sweeps away all that lies within the reach of it: the water-spout is one of the strangest sights in nature, and, from the accounts we have of them, they seem, in some instances, to be derived from the same cause with thunder and lightning; in others, from a whirlwind beginning in the clouds and extending to the earth. Upon the coast of Barbary, they have appeared as a sequel to thunder and lightning of many hours continuance. A heavy cloud lets fall a part of itself in a conical form, as a tunnel or pipe, which preserves its continuity from the cloud to the sea. In concert with this appearance, there commences, at the same time, a pillar of water from the sea, with a dashing and scattering of the waves at the base of it, which uniting itself with the spout, they both work together in a furious manner; the spout whirling round with a spiral motion like that of a screw, the column of water rising up at the same time through a canal or pipe in the middle of it, something after the manner as water is raised in the screw of Archimedes. From all which it seems as if the clouds, instead of discharging their fire by flashes in the ordinary way, do it in a continued stream by the mediation of their water; the sea from

beneath

beneath at the same time rushing towards it to restore the equilibrium, and flying as smoke up a chimney to mix with the water of the cloud. Thus they continue for some time feeding and saturating each other till the cause of the motion expires, when the sea and the cloud come nearer to an equality, and the pillar breaks asunder in the middle. Thus they will proceed, breaking and reforming themselves several times in a quarter of an hour, and moving along gradually at the same time in the direction of the wind. Sometimes the dashing, scattering, and elevation of the water from the sea, appears without any corresponding projection from the clouds above; which shews that the cause of this phænomenon resides partly in the sea itself; as indeed it is well known to all electricians, that, in our experiments, the fire is active both in the attracting and the attracted body *.

When

* I have no doubt in my own mind, that the water-spout is among the number of electrical phænomena; but I find an extraordinary confirmation of it, which was lately taken notice of by Mr. Cavallo in his Treatise on Electricity, viz. that a flash of lightning was seen at the time when a water-spout was broken and disappeared. See Mr. Forster's Account of Capt. Cook's Voyage. Vol. I. p. 190.

When a water-spout happens in this climate, which is very rarely, it seems rather to be the effect of a whirlwind; though how any wind can have such force in so small a compass, but in virtue of its co-operating with an electrical blast from a thunder-cloud, is more than can be conceived. A curious gentleman, who had an opportunity of observing one within three hundred yards of him, found that it proceeded from a gyration of the clouds, by contrary winds meeting in a point or centre. The clouds, which appeared very black, were hurried round violently by a wind aloft, while there was none below, and a whirling noise was heard like that of a mill. After a while a long tube, or spout, came down from the congregated clouds, in which was a swift spiral motion like that of a screw. It travelled slowly from west to north-east, and broke down a great oak tree or two. The people who were in the field fell down flat upon the ground, to escape being whirled about and killed by it, as they saw many jackdaws to be, that were suddenly catched up and carried out of sight, and then cast a great way off among the corn. At last it passed over the town of Hatfield in Yorkshire, to the great terror of the inhabitants, filling

filling the air with the thatch it plucked off from the houses; then touching upon the corner of the church, it tore up several sheets of lead, and rolled them strangely together; soon after which it was dissipated without farther mischief*.

In the torrid zone, the water-spout is sometimes attended with an effect which appears supernatural, and will scarcely find credit in this part of the world; for who will believe that fish should fall from the sky in a shower of rain? A gentleman of veracity, who spent many years in the East-Indies, declares to his friends that he has been witness to this several times; but speaks of it with caution, knowing that it will be thought incredible by those who are not acquainted with the cause. I have a servant, a native of the West-Indies, who assures me he was once a witness to this fact himself, when small fishes, about two or three inches long, fell in great numbers during a storm of rain. The spot where this happened was in the island of Jamaica, within about a mile of the sea. When water is carried with violence from the sea up the column of a spout, small fish, which are

* See the Account of this by Mr. De la Pryme, Phil. Trans. Abr. vol. v. p. 214.

are too weak to escape when the column is forming, are conveyed up to the clouds, and fall from them afterwards on land not far distant from the sea.

Weather depends upon the Disposition of the Land.

Something has been said already to shew, that though the temper of a climate depends chiefly and generally on its latitude, we nevertheless find sultry heat and intense cold where neither could be expected. By the disposition of the land, I mean its exposure to the winds, and the course of the mountains that are found in it.

The writer of Anson's voyage gives us a relation much to our present purpose. He tells us, that while they coasted near the land of South America, which has those vast ridges of mountains, the Andes and Cordellieras, the air was rendered very temperate by the winds which blew over those snowy mountains, though they were then near, and even under the line: but when they had passed beyond this tract of land, and sailed by the isthmus of Darien, where the country is flatter, the air became insupportably close and sultry.

Where

Where the rivers of Indus and Ganges enter the Indian ocean, they have a large country between them, which is divided in the midst by a ridge of very high hills, which run nearly from north to south. On the western coast is Malabar, and on the east Coromandel. This land being within the limits of the monsoons, has the wind for six months on one side of these hills, and six months on the other: but on the windward side, where the vapours are stopped in their progress, and condensed by the mountains, there it is winter; while on the leeward side, at no more than twenty leagues distance, it is summer; and so alternately, according to the season, you may ascend one side of those mountains with hot summer weather, and descend on the other into a stormy winter. The like is said to occur in some other parts of the globe.

Rain follows the Hills.

In all countries the weather is remarkably affected by tracks of hills and mountains; and we have many opportunities of observing this in our own country. The county of Kent is divided almost throughout by a branch of the Chiltern hills, down to the

cliffs of Dover. A heavy thunder-cloud moving right before the wind, and threatening to come over head in the lower country, is frequently seen to break before its arrival into two different storms, which both take the direction of two ridges of the hills, and go off without touching the country below. Hills arrest the vapours in their passage, by standing in their way; they condense them by their coldness; and even distant clouds are impelled toward them as they are floating in the air: on all these accounts, a country that has many hills is never long without much rain. While the rain at Paris is only nineteen inches yearly on an average, it is forty inches at the foot of the hills in Lancashire. By the wise appointment of Divine Providence, hills which are more thinly clothed with vegetable earth, so much exposed to the sun and winds, and which, by reason of their declivity, so quickly lose what they receive, have all that excess of rain which is requisite to their welfare; while the vallies and plains, which are better clothed, and retain what they get, have so much less; but still in proportion to their wants. The land of Palestine, abounding every where with hills, is celebrated for its felicity in being every-

where

where well watered with *the former and the latter rain;* its mountains refreshed with dews; its vallies verdant, and fruitful with springs and rivers; while the flat and level country of Egypt has a cloudless sky, and is seldom or never visited with a shower: it is therefore described as a land which the inhabitants are obliged to water *with their foot*, that is, to attend upon it, and supply what is wanting from the heavens by their own personal labour. But here it is equally to be admired, that this country derives a singular benefit from the remote snowy mountains of Abyssinia, which give their waters annually to the Nile, that runs through the heart of Egypt, and overflows the country by what we may call a *local miracle*; for the case has not its parallel in the whole world.

Trees occasion Vapours and Rain.

But the effect of hills, in giving showers to a country, is never so remarkable as when they are covered thick with trees and woods. A philosophical gentleman, who was employed as a commissary for the ceded islands, has described this so learnedly and elegantly from his own observation, that I shall use his words: "Clouds, which are borne through

 the

the regions of air, are interrupted, impeded, or attracted by lofty lands and woods, and hang upon the mountain tops till they fall in showers; whilst on the other hand the intense heat of the sun draws such vapours from the ground, and the everlasting trees on inaccessible heights send forth such exhalations from their branches, as moisten the impending atmosphere, and circulating again revisit their parent earth. The effects of these principles are curious and surprising to those who contemplate them on the spot. The smooth polished Barbadoes, and our Leeward Islands, are seen parched up, and perishing with drought; whilst the towering and rugged Dominica, St. Vincent, Grenada and Tobago, are found to enjoy incessant rains and delicious verdure *." It is generally agreed, that the clearing away of the woods lessens in tract of time the vapours, and consequently the rain of a country. In the province of Pennsylvania in America, the running waters are much less than formerly; and it is imputed to the cutting down of their forests. Several fine parishes in Jamaica, which used to produce large crops of sugar-canes, and

* Young's Observ. on our New West India Colonies, p. 26. anno 1764.

and were once the richest spots in the island, are now become dry for nine months in the year, and are turned into cattle-pens, through the clearing away of the neighbouring woods.

Hot Air from a Sandy Desert.

The nature of the soil in the neighbouring tracts of land, over which the winds blow to us, has a great effect upon the quality of the air. The vast sandy deserts of Africa and Arabia give a burning heat and blasting quality to the winds that pass over them. These torrid regions lie to the southward and eastward of the Mediterranean: and hence it is that travellers, who have had the opportunity of making the comparison, tell us, that the air of the West India islands is nothing to the hot suffocating winds which blow in the night at Gibraltar and Minorca, &c. for that these latter are scarcely supportable by the human frame. On the coast of Africa itself, they are, at some times, destructive and deadly to those who are exposed to them. A curious person, who had resided at Goree, in the river Senegal, told me, there is an easterly wind from the inland parts, with which they who are suddenly met by it in the face are scorched up as by a blast from a furnace.

A very extraordinary blasting wind is felt occasionally at Falkland's Islands, which lie nearly in the same latitude with London: Captain Clayton, in the Transactions for the year 1776, gives this account of it: "The winds from E. to S. are most pernicious, blighting, and tempestuous: they affect men, birds, beasts, and vegetables: nothing can stand it which is exposed. Happily its duration is short; it seldom continues above twenty-four hours. It cuts the herbage down, as if fires had been made under them; the leaves are parched up, and crumble to dust. The fowls are seized with cramps, so as to become lame, and never recover; but continue to decline till the whole side is decayed which was first affected. Hogs and pigs are suddenly taken with the staggers, turn round, and drop, never to recover. Men are oppressed with a stopped perspiration, heaviness at the breast, sore throats: but they soon get over it by due care." The wind, which the Italians call the *Siroco*, has of late been particularly described by travellers. It is so called, because it blows from Syria; and sometimes it lasts for several days, to the great annoyance of natives, but more especially of strangers. In the scale of

heat I have set down its temperature at 112 degrees, from Mr. Brydone. Its effect in relaxing the body and depressing the spirits is to be conceived only by those that have felt it. In the South of France they have it in a lesser degree, and call it the Levant wind; but its effects are still very remarkable. It suspends the powers of digestion, so that they who venture to eat a heavy supper when this wind prevails, are frequently found dead in their beds, of what is called an indigestion. The sick at that time so commonly sink under their distempers, that it is usual to inquire in the morning, who is dead, after this wind has blown in the night.

But beyond all others we have yet heard of in this kind, is the *Samiel*, or mortifying wind of the deserts near Bagdad, lately described by Mr. Ives, in his Voyages and Travels over land from the East Indies.* They have notice when this wind is approaching by a certain appearance in the air; and the camels, either by instinct or experience, are so well aware of it, that they are said to make an unusual noise, and cover up their noses in the sand. Travellers, to escape the effect of it, throw themselves as close as possible to the ground, and wait till it is over-

past, which is commonly in a few minutes. As soon as they who have escaped with life dare to rise again, they examine how it fares with their companions, by plucking at their arms and legs; for if they are destroyed by the blast, their limbs are absolutely mortified, and will come asunder. What it can be besides heat which the air contracts in passing over, or transpiring from the soil of a vast sandy desert, to give it this astonishing effect upon an animal body, is more than I can explain or conjecture; but such is the fact as it is related. And now, after this relation, little doubt is to be made, but that the strange destruction which fell upon the army of Sennacherib *, the blasphemous Assyrian, was occasioned by one of these deleterious winds: for the power of God, in all cases that will admit of it, works with natural causes: and it is expressly declared, in the sentence passed upon this man and his people, "Behold, I will send a *blast* upon him;" the original is *ruach*, a *wind*, by which nothing can be so properly understood as this blasting wind; under the influence of which, they that lie down, how many soever they may be in multitude, are subject to be changed

* See Isa. xxxvii.

changed by a sudden stroke into dead corpses. There are two particulars in regard to this deadly wind which ought not to be forgotten: the first is, that if it happens to meet with a shower of rain in its course, and blows across it, it is at once deprived of its noxious quality, and becomes mild and innocent: the other is, that it was never known to pass the walls of a city. Its name is *Samiel,* which, if I interpret it rightly, was intended to signify *destruction from God;* and indeed the effect of it, to our apprehension, seems to exceed the powers of nature.

Air tempered by the Sea.

As the air is heated thus violently, and infected by blowing over a vast sandy desert, so it is very probable, by parity of reason, that the vast body of water in the sea, which lies contiguous to the air, must have a great effect in tempering the heats of the torrid zone, and we find it to be so in fact by the coolness of the sea-breezes. This gives us an admirable reason why the sea is so largely distributed about the middle region of the earth, and the land contracted to a much smaller extent than in the higher latitudes. This, in the western hemisphere, is very remarkable

markable about the isthmus of Darien; and not much less so in the eastern. The air of a room is made more temperate in summer by a floor of stone or brick, and still more so by a fountain or bason of water, which is therefore so commonly introduced in Persia, Turkey, and the countries of the East, as an article of luxury, and part of the furniture of the house. The air over the sea is never violently hot, unless in some harbour, or near some coast, where it is affected by the land. This may be one reason why there is so great a proportion of sea in the terraqueous globe, to mitigate the heats from the land, and keep the atmosphere properly qualified, and reduced to what is most agreeable to the human constitution.

Prognostic Signs of the Weather.

Having thus far treated of the appearances and causes of the weather, (imperfectly, as I must own, the subject being by far too copious to be exhausted,) we come now to the prognostic signs, which enable us to presage what weather is approaching. These are so many, that Virgil was bold enough to affirm, no shower ever did damage to any man, without

out giving him proper warning*. This may be true in general; and probably more true in the climate of Italy, where Virgil wrote and made his observations, than in such a variable atmosphere as that of England, where it sometimes requires more experience and sagacity than falls to our share, to pronounce whether the clouds that are approaching will fall in rain. We are now happily provided with an instrument, which gives us a more compendious rule than the ancients were possessed of, unless they had something equivalent upon the same principle: though it may be said, for the credit of collateral observation, that the falling of the mercurial column in the barometer is generally attended with certain symptoms in the air, which, as they speak the same language with the barometer, will give us their information either with the barometer or without it. From the barometer we judge of the weather by this general rule, that when it sinks, the air, being lighter, (from whatever cause,) will let fall its vapours, and give us rain; and that when the mercury rises, the air, being heavier, will be able to support them, and we shall have fair

* ——— *nunquam imprudentibus imber*
Obfuit——— Georg. Lib. i. p. 373.

fair weather. If the mercury sinks in a frost, we expect snow, or a thaw; when it rises in winter, we expect a frost, especially if the wind is in the north or east. Our next rule is to observe the progress of its descent: if it sinks slowly and gradually, we have reason to expect that the rain will be lasting; and if it rises gradually, there will be a continuance of fair weather. When it fluctuates, rising and falling by turns, and that suddenly, the weather abroad is generally as unsettled as the instrument, and for the most part continues so for some time. If it falls very low, there will be much rain; if suddenly, a very high wind; if lowest of all, a stormy and tempestuous wind. But if such an extraordinary fall happens without any remarkable alteration near at hand, there must be storms at a distance; perhaps an earthquake in some other country. I remember seeing the barometer (Nov. 22, 1768,) fall to the very bottom of the scale, exactly down to the cypher, while nothing happened with us to account for it; the rain had been heavy the day before, but on this day the weather was fine, with little rain and no wind. But I was afterwards informed by a correspondent, there had been an earthquake on that

very

very day at Naples. Before we heard of this, we had concluded the cause must rather have been within the earth than without it.

The usual ranges of the mercurial column in this latitude are comprehended between 28 inches and 31; of which the middle, or 29½, is the station of the barometer in variable weather, when there is a mixture of showers and sunshine. Near the pole the variations of the instrument are much greater; between the tropics much less. I never yet saw it so high as 31 inches, and but once so low as 28.

Its descent is not always a sign of approaching rain, because it often falls very much for a wind even without rain; and its rising is no sure sign of fair weather if the wind is northerly or easterly, in which case it often stands high, by reason of the coldness and density of the air, though it is all the while rainy weather. When fine weather is lasting, with a westerly wind, it frequently rests at a point above the changeable mark, but somewhat below thirty inches.

Upon the whole, whether the barometer, by its sinking, indicates the levity of the air, or the rising of vapours, it is the best rule we have for the predicting of the weather: and for

for the many applications of which it is capable, the instrument is one of the greatest acquisitions Natural Philosophy can boast of. But there are cases in which it will either mislead, or give us little information. It will sink very much for weather with which we are not affected, as happening at a great distance: it will rise with particular winds, though they are attended with rain or snow; and the same has been observed at Rome, that the barometer stands high in autumn, though many and long showers fall. I have seen the barometer continue high for several days with very little variation, when there has been much rain and snow, with a cold blustering wind from the north-west. In the summer months, when there is most rain, it does not vary so much as in winter. It will sink with a wind which brings no rain, and it will sometimes give no warning at all of a change that is coming on, when there are manifest signs of it abroad in the elements; as for example, it gives little notice of the rains that come with thunder: and lastly, between the tropics it has little or no variation at all, except in a hurricane, and then it gives notice of it only when it is present. I shall therefore proceed to point out those other

other prognostics of the weather, which are independent of the barometer, and may supply the defects of it.

Signs from Vapours.

As there can be no rain but from vapours and clouds preceding, we naturally attend to these in the first place. When vapours rise, either from the water or the land, we are anxious to know what will become of them, and therefore we watch their motions diligently. If a white mist in the evening or night is spread over a meadow wherein there is a river, it will be drawn up by the sun of the next morning, and the day will be bright afterwards. Many of these may go up into the air successively, before it becomes overcharged so as to produce rain. A shepherd in Essex had a doctrine, which he said had been confirmed to him by long observation; that after the sky had taken up five or six fogs, it was pretty sure to send them down again in rain: so he made it his practice to keep a register of the fogs upon a stick, and according as the numbers stood, he predicted when the rain was to follow. Where there are high hills, and the mist which hangs over the lower lands draws toward the hills in a morning,

morning, and rolls up their sides till it covers the top, there will be no rain. In some places, if the mist hangs upon the hills, and drags along the woods, instead of overspreading the level grounds in a morning, they will turn to rain; therefore, to judge rightly from the appearances of a fog, it is in some degree necessary to be acquainted with the nature of the country; as it is necessary in a physician to understand the particular constitution of the patient, as well as the general symptoms of the disease.

Signs from the Clouds.

From the clouds there are many signs; for a cloud is one degree nearer to rain than a fog is. We are apt to imagine, that clouds always rise upwards from some place or other in the form of clouds, nearly the same as they afterwards appear when they are driven about by the wind. But the formation of clouds is one of the chemical mysteries of nature; they are frequently generated in the sky itself. The air of the clearest sky sustains a large quantity of vapour, which is the occasion of its blue colour, but so finely diffused and incorporated, that the fluid of air seems to be transparent and simple. The formation

formation and solution of the clouds are often manifest to the sight. If we watch the clouds attentively for some time together, especially in a summer's evening, we shall see them lessen by degrees, and at length melt away totally into the air, till they are no longer visible. In company with another observer, I have often taken the angle of the clouds at two stations, to find their true height at different seasons. When we have fixed upon a cloud proper for our purpose, and have been waiting for its approach, it has wasted away and disappeared entirely before it reached the intended point of observation: and I look upon it as one very considerable symptom of fair weather, when the clouds thus decay and resolve themselves into air. But it is otherwise when they are collected out of it. There are times when they increase very fast in magnitude and density. The sky, which has long been serene and blue, becomes fretted and spotted with innumerable small clouds, bearing some resemblance to the waves of the sea, or the party-coloured back of a mackarel. At first they are thin, white and fleecy; but by degrees grow dark and black. Such clouds are generated in the sky itself, at about the height

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of three quarters of a mile. Thus a transparent compound liquor, when a separation takes place in it, becomes turbid, and deposits a sediment. The formation of clouds, and the falling of rain, is a chemical precipitation of moisture from the air, which may be brought to pass three different ways, either by an overcharge of vapour more than the air can support; or by a prevailing of cold in the upper air, which condenses the vapours; or, lastly, by an unusual warmth in the lower air, which occasions a rarefaction.

From this faculty in the air, of condensing its own vapour, the Greeks called their Jupiter νεφεληγερέτης, cloud-congregating; the expression of Virgil, *in nubem cogitur aer*, "the air is collected into a cloud," is strictly physical and agreeable to fact. Against heavy rain every cloud rises bigger than the former, and all the clouds are in a growing state. This is most remarkable on the approach of a thunder storm, after the vapours have been copiously elevated, suspended in the sky by the heat, and are highly charged with electrical fire: small fragments of flying clouds increase and assemble together, till in a short space of time they cover the sky.

Thus,

Thus, after that great drought in the days of Elijah, a cloud seemed to arise out of the sea, (that is, from the horizon of the sea,) no bigger than a man's hand, which soon overspread and blackened the whole heaven. When the clouds are formed like fleeces, deep and dense toward the middle, and very white at the edges, with the sky very bright and blue about them, they are of a frosty coldness, and will soon fall, either in hail, snow, or in hasty showers of rain. In clouds of this sort the parhelia or mock-suns are seen, which are occasioned by a reflection of the true sun from an icy cloud; and for this reason they are so much more common in the countries nearer to the north pole, than with us in England, where they are so rare that I never saw this phænomenon more than once in my life. There are frequently two of them appearing at the same time, one on each side the sun, with a luminous arch of a circle intersecting them both, which arch is sometimes coloured.

If clouds are seen to breed high in the air in thin white trains like locks of wool, or the tails of horses, they shew that the vapour, as it is collected, is irregularly spread and scattered by contrary winds above; the conse-

quence of which will soon be a wind below, and probably rain with it. This is so frequently experienced, that the sea-faring people have a vulgar proverb, signifying, that when these marks appear in the air, the ships will soon be obliged to lower their sails. That stormy wind so well known on the coast of Virginia, &c. and called the North-Easter, is always preceded by the appearance of a cloud of a particular form and colour, whence the seamen know with certainty what they are to expect. From the complection of a single cloud, with white edges and dark diverging lines from the skirts of it, I ventured to predict with certainty a high wind forty hours before it began: when we had indeed a storm of the first magnitude, which lasted for two days and nights, and did great mischief. If I had been a seaman, such a warning would have driven me (as I think) into the first harbour I could have found; and probably the same threatening appearance had its effect with many, who, by using the sea, are better acquainted with the face of the sky. If the clouds, as they come forward, seem to diverge from a point in the horizon, a wind may be expected from that quarter, or the opposite.

When a general cloudiness covers the sky above, and there are small black fragments of clouds like smoke flying underneath, which some call messengers, and others Noah's Ark, because they sail over the other clouds like the ark upon the waters, rain is not far off, and it will probably be lasting. There is no surer sign of rain than two different currents of clouds, especially if the undermost flies fast before the wind; and if two such currents appear in the hot weather of the summer, they shew that a thunder storm is gathering. But the preparation which precedes a storm of thunder is so generally understood, that it is needless to insist upon it minutely.

From the Dew.

The phænomena of the dew are nearly allied to those of clouds and vapours. If the dew lies plentifully upon the grass after a fair day, another fair day may be expected to succeed to it; but if after such a day there is no dew upon the ground, and no wind stirring, it is a sign that the vapours go upwards, and that there will be an accumulation above, which must terminate in rain.

From the Face of the Sky.

From the face of the sky, the Scripture itself authorises us to form a judgment of the weather; and the rules there laid down, being founded in nature, are such as will seldom deceive us even in this climate, different as it is from that of Judea: "when "it is evening, ye say it will be fair weather, "for the sky is red; and in the morning, it "will be foul weather to-day, for the sky "is red and lowring." The colour of the sky is an index to the weather, because it shews the state of the vapours in the atmosphere. The heat of the day raises much vapour from the earth, and the rays of the sun refracted by them take a red colour in the evening. These vapours are naturally precipitated by the cold air of the night, and then the sky is clear in the morning; but if this does not happen, and they remain still in the air, the light of the morning will be coloured as it was in the evening, and rain will be the consequence. If I conjecture right, there is commonly either a strong dew or a mist over the ground between a red evening and a grey morning; but if a red morning succeeds, there is no dew. It is

is a bad symptom when a lowring redness is spread too far upwards from the horizon, either in the morning or in the evening; it is succeeded either by rain or wind, and frequently by both. When such a fiery redness, together with a raggedness of the clouds, extends towards the zenith in an evening, the wind will be high from the west or southwest, attended with rain; and I have sometimes seen this appearance succeeded by a flood. Before the late dreadful hurricane of 1780, at Barbadoes, and the other West Indian Islands, a redness like fire was observed all over the sky.

When the sky, in a rainy season, is tinged with a sea-green colour near the horizon, when it ought to be blue, the rain will continue and increase; if it is of a deep dead blue, it is abundantly loaded with vapours, and the weather will be showery. I have seen this deep blue sky immediately change its aspect upon the setting of the sun, and appear all overcast with one uniform cloudiness.

The sun, moon, and stars, have always been supposed to give notice, by their appearances, of an approaching change in the weather; and very justly, because they shew

us the state of the vapours. When there is a haziness aloft in the air, so that the sun's light fades by degrees, and his orb looks whitish and ill-defined, it is one of the most certain signs of rain. If the moon and stars grow dim in the night, with the like haziness in the air, and a ring or halo appears round the moon, rain will be the consequence.

From the Sun, Moon, and Stars.

If the rays of the sun breaking through the clouds are visible in the air, and appear like those horns of irradiation which painters usually place upon the head of Moses, the air is sensibly filled with vapours, which reflect the rays to the sight, and these vapours will soon produce rain. They seem to diverge from the sun, when in reality they only converge from the eye according to the laws of perspective, as any other parallel lines do when they are continued to a great distance. If the sun appears white at his setting, or shorn of his rays, or goes down into a bank of clouds which lie in the horizon; all these are signs either of approaching or continuing bad weather. If the moon looks pale and dim, we are to expect rain; if red, it is a sign of wind; and if white,

and of her natural colour, the sky is clear, and it will be fair weather; according to a poetical adage,

Pallida Luna pluit, rubicunda flat, alba serenat:

With regard to the monthly course of the moon, though something has already been said of it as it affects the weather, I shall here add, from repeated observation, that if the moon is rainy throughout, it will clear up at the ensuing change, and the rain will probably commence again in a few days after, and continue; if, on the contrary, the moon has been fair throughout, and it rains at the change, the fair weather will probably be restored about the fourth or fifth day of the moon, and continue as before*. By this rule, and but little assistance from my barometer, I have made hay for more than twenty years, and have never once had the mortification of seeing it damaged by the rain. A farmer, who has much business to do, cannot contract his work into so small a compass as to save himself by the benefit of this

* Sui ortu quarto (namque is certissimus auctor)
Pura, neque obtusis per cœlum cornibus ibit,
Totus et ille dies, et qui nascentur ab illo
Exactum ad mensem, pluvia ventisque carebunt.
Virg. Georg. i. 432.

this observation, because some of his work must be done to make way for the rest; but a gentleman, who cuts hay for his own consumption, will seldom fail to find his account in it.

Superstition has given some laws to the moon which are deservedly ridiculed, and tempt people to suspect that astronomy and philosophy judge to as little purpose when they attempt to foretel the weather. In the south of England there is a notion universally prevailing among the common people, that if the moon changes on a Saturday it will bring a flood with it; the same is expected in the north of England if it changes on a Sunday. Both these predictions are equally groundless, and confute one another. Whence such an opinion could arise, I am not able to conjecture; unless, peradventure, some astronomer pretended to have discovered, that the moon which brought the flood of Noah changed on one of these days of the week, and thence concluded that the moon, on the same day, would be attended with something of the like consequence to the end of the world.

From the appearance of the moon and stars, and of the sun, at the Caribbee Islands, the native

native Indians are said to predict the hurricanes, which are so terrible in that part of the world, a fortnight before they happen. A sea-faring gentleman obtained the following prognostics from an Indian.

All hurricanes come either on the day of the full, or change, or quarters of the moon. If it is to come at the full, then at the preceding change the sky is troubled, the sun more red than usual, there is a great calm below, the trade-wind stops, and the fogs disappear from the mountain tops, which seldom happens. In the caverns of the earth, and in wells, there is a hollow noise like that of a storm; and at night the stars have burrs about them, the sky looks black in the north-west, the sea smells stronger than usual, and sometimes on that day the wind blows hard for an hour or two westerly, out of its usual course, the Caribbee Islands being at all times subject to an easterly trade-wind. If the hurricane is to happen at the change, then you have these signs at the full next before it; and if at a quarter, then the like prognostics fall upon the preceding quarter. The captain, who had received this information, observed the signs, and gave notice

to

to the English ships of war that were then lying at one of the Caribbee Islands, who all made ready for sea, and came back in a few days after they had rode out the hurricane in a wide sea. This kind of storm always blows in direct opposition to the trade-wind, which occasions a dreadful struggle and commotion before the air is settled again into its regular course. But it is time now to inquire what prognostics we have from the wind.

Signs from the Winds.

When the wind veers about uncertainly to several points of the compass, rain is pretty sure to follow. There is a large tract of sea at a distance from the coast of Guinea, where, at all times, there is either a calm or a variable wind. A fleet of ships within sight of one another, shall each of them have a different wind, and that but of short continuance. Here the rain is so frequent, that navigators give to this tract of the sea, the name of *The Rains*. By variable and opposite winds, eddies are formed, and the clouds being driven different ways, run foul of each other, and are congregated and condensed

till

till the air can no longer support them. The barometer, when these changeable winds are abroad, is generally low. Some have remarked, that if the wind, as it veers about, follows the course of the sun, from the east towards the west, it brings fair weather; if the contrary, foul.

But there is no prognostic of rain more infallible, than a whistling or howling noise of the wind. The south wind is most apt to have this effect, because it brings with it the most vapour; but I believe any wind that is moist enough will produce the like sound; and it is probable that the consequence of this humidity in the wind is the same in every climate. The Sacred History seems to agree with this; for the prophet Elijah, before any other symptom of the weather appeared, seems to have given notice to Ahab from this one.—"*Get thee up, eat* "*and drink,*" said he, "*for there is* a sound "*of abundance of rain:*" then it follows, that the heaven was soon "*black with clouds and wind, and there was a great rain.*"

The sea itself is not wanting in its signs; and many more of these may be known to seamen than have ever fallen in my way. If, in

in a calm, the sea is observed to work or move in any particular direction, a wind will surely follow the next day in the same direction. The sea of the bay of Naples is particularly agitated, and swells some hours before the arrival of a storm: and without all doubt there are numberless instances of the same sort in other parts of the globe; because there is a mechanical reason for this prognostic. If at night the sea-water, when it is struck with an oar, or rushes into the wake of a ship, is luminous or fiery, a south wind will follow. It so happened that, when at night this observation was made to me, at the only opportunity that ever occurred, the wind turned to the south the morning afterwards, and brought showers with it. Whether this happens with any constancy, is more than I have any warrant to affirm upon my own experience.

An alteration of the weather is frequently portended by nocturnal meteors. When an Aurora Borealis appears after some warm days, it is generally succeeded by a coldness of the air, as if the matter of heat was carried upwards from the earth to the sky. Those meteors which fly along with a train of fire, and

and are vulgarly called shooting-stars, are supposed to shew that wind is impending*. By a late observation I have been induced to refer these, as well as the Aurora Borealis, and the water-spout, to the class of electric phænomena. In the month of August 1780, a black cloud in the horizon, at the south quarter, brought thunder and lightning at the dusk of the evening, but never came very near us. As soon as it was dark, a gentleman walking abroad was surprised with an unusual shooting of these meteors, and called me out to be a spectator of them. In the space of one quarter of an hour, I counted thirty-three of them; and it was remarkable, that whatever quarter of the sky they started from, their trains all pointed to the thunder-cloud without any exception, though all seemed to expire before they reached it.

In the animal creation, there are many prognostics which give us notice before a change of the weather takes place. Brute creatures are in many respects more acute in their feelings and senses than mankind; and as

* *Sæpe etiam stellas,* vento impendente, *videbis*
Præcipites cælo labi, noctisque per umbram
Flammarum longos a tergo albescere tractus.
Virg. Georg. I. 365.

as their motions signify their sensations, we can tell what is about to happen. So long as the swallows fly aloft after their prey, we think ourselves sure of a serene sky: but when they skim along near the ground, or the surface of the water, we judge that rain is not far off, and the observation will seldom fail. In the year 1775, a drought of three months continuance, broke up at the summer solstice: the day before the rain came upon us, the swallows flew very near the ground, which they had never done in the fine weather.

In the mountainous country of Derbyshire, which goes by the name of *The Peak*, the inhabitants observe, that if the sheep wind up the hills in the morning to their pasture, and feed near the tops, the weather, though cloudy and drizzling, which is very frequently the case in those parts, will clear away by degrees, and terminate in a fine day; but if they feed in the bottoms, the rain will continue and increase.

Dogs grow sleepy and stupid before rain, and shew that their stomachs are out of order by refusing their food and eating grass, that sort which is hence called *dog's grass:* this they cast up again soon afterwards, and with

it

it the foulness that offended their stomachs. Water-fowl dive and wash themselves more than ordinary; and even the fish in rivers are affected, because all fishermen agree, that they never bite freely when rain is depending. Flies, on the contrary, are particularly troublesome, and seem to be more hungry than usual; and toads are seen in the evening, crawling across the road or beaten path, where they seldom appear but when they are restless with an approaching change *.

Many things of this sort are poetically and beautifully represented by Virgil in his *Georgics;* the substance of which I shall give to the reader in the words of the late Dr. Woodward, whose descriptions are vigorous and entertaining. "Before any considerable quantity of rain is to fall, most living creatures "are affected in such sort as to render them "some way sensible of its approach, and of "the

* The echinus, or sea-urchin, has an orbicular shell, which is covered all over with spines or prickles, which are easily broken off if the waves of the sea dash its body against the shore. To prevent this, it is said to load its shell before a storm with sand and pebble-stones, to give weight to its shell, and keep it steady at the bottom. This is related by Pierius, in his Hieroglyphica, lib. xxviii. c. 73. Ambrose and Basil speak of the same fact as a wonderful example of instinctive prescience in brute animals.

" the access of something new to the surface
" of the earth and of the atmosphere. Moles
" work harder than ordinary; they throw up
" more earth, and sometimes come forth: the
" worms do so too. Ants are observed to
" stir about, and bustle more than usually
" for some time; and then to retire to their
" burrows before the rain falls. All sorts of
" insects and flies are more stirring and busy
" than ordinary. Bees are ever on this
" occasion in fullest employ; but betake
" themselves all to their hives, if not too far
" for them to reach before the storm arises.
" The common flesh-flies are more bold and
" greedy: snails, frogs, and toads, appear
" disturbed and uneasy. Fish are sullen, and
" made qualmish by the water, now more
" turbid than before. Birds of all sorts are in
" action: crows are more earnest after their
" prey, as are also swallows and other small
" birds, and therefore they fall lower and fly
" nearer to the earth in search of insects and
" other such things as they feed upon. When
" the mountains of the north begin to be
" capped with fogs, the moor-cocks and other
" birds quit them, fly off in flocks, and be-
" take themselves to the lower lands for the
" time. Swine discover great uneasines; as
" do

"do likewise sheep, cows and oxen, appear-"ing more solicitous and eager in pasture "than usual. Even mankind are not ex-"empt from some sense of a change in their "bodies*." The relation between the human body and the weather is of so much consequence, that I shall make it a subject by itself, and with that conclude the present Discourse.

The air affects the human body by its weight, its moisture, its dryness, its heat, and its cold. There are two forces which act upon the animal frame, and they are both equally necessary to the keeping up of vital heat and vital motion. The one force is that of the atmosphere pressing without upon the surface of the body; the other is that of the air expanding it within; and these two ought to be a counter-balance to one another. When the barometer is high, the superficial pressure is in force on the outside of the body; by which the fibres are strengthened, the coats of the vessels re-act upon their contents, the blood is propelled, the secretions are promoted, the body feels active, and the mind is in vigour. Athletic constitutions, inured to the inclemencies of the weather, feel little or no in-

 convenience

* See Woodward's Letters to Sir R. Southwell.

convenience from any change; but where the frame is tender or sickly, it is sensible of depression and relaxation when the weight of the air is lessened: the force within is not sufficiently counterbalanced; the re-action of the solids upon the fluids is weaker; the blood takes up too much room; all the humours are rarefied; the coats of the vessels are distended, and the solids themselves, that is, the muscular parts of the body, are inflated: in consequence of which, there is a sense of languor and weakness; the limbs are pained by fits; the head is vapoured; the body is inactive; the mind is dispirited, and all the faculties are less vigorous than usual.

When the air is too moist, it draws off the vital heat, occasioning a sensation of cold and chillness all over the skin; consequently it checks perspiration, impoverishes the blood, and, by increasing the serous fluid, it brings on agues, intermittents, dropsies, putrid sore throats, &c. Air which is too dry, as that of the north and north-east commonly is, takes off only the finest parts of the animal fluids in perspiration, and occasions a viscidity of the blood; which is followed by a variety of distempers, according to the different constitution of the body. In phlegmatic habits,

bits, it brings on a vapid lentor of the blood; in those which are more sanguine, fevers, pleurisies, and other distempers of the inflammatory kind. During an epidemical small-pox at Plymouth, the late learned Dr. Huxham had an opportunity of observing how the secretions, particularly that of salivation, was interrupted by the blowing of a strong easterly wind for seven or eight days together. Other physicians have remarked, that people expectorate very little in disorders of the breast, when cold dry easterly winds blow; whence asthmatic patients are apt to be troubled more than ordinarily on such occasions. The same constitution of the air which increases any disorder, will not fail to produce it, if it continues long enough: therefore long east winds, or north-east, by depriving the blood of its finer parts, bring on pleurisies, and other like disorders which arise from viscidity.

Extreme cold is more sensibly hurtful to the body, because it gives immediate pain. The air near the pole is full of icicles, and those sharp and penetrating like needles, so that they wound and blister the skin: and if the body is too long exposed to such an air, the extremities are apt to mortify. When

 persons

persons are long exposed to a frosty wind in the field, especially if there is snow with it, and the cold penetrates too deeply into the body, a torpor and sleepiness comes on, which is invincible, and ends in death.

The violent heats of Gibraltar and the East Indies waste the body and the strength by keeping up a profuse perspiration. They dry up some of the humours, and exalt others, till they raise calentures, yellow fevers, black vomit, and all kinds of bilious disorders. Every person who values his health and safety, should think it worth his while to consider what caution is requisite on different occasions; what regimen is the best under different circumstances; and what remedies are to be applied in case of danger from the air of different places, and the weather of different seasons.

To strengthen the body against the evils that arise from a change in the weight of the air; there are no better rules, than, first, to inhabit an airy house rather than one too warm, too close, and with apartments too low: secondly, to use exercise, especially on horseback, in the open air, and in all sorts of weather; because nothing is of more use to strengthen the relaxed solids, help digestion,

and

and promote all the secretions: thirdly, to use the cold bath; by which the elastic reactive power of the vessels is kept up, so as to enable them to resist the effects of a lighter and relaxing air, and to secure the skin against taking cold from the impressions of the weather. But this last preservative is not to be used by infirm people, at all adventures, without good advice and necessary preparation. A warm bath may generally be used with much less danger to the patient than a cold one, and in many cases with so much advantage, that I am convinced we do not use it near so frequently as we ought to do in viscidities and disorders that arise from obstructed perspiration.

Against the effects of a moist air, solid diet, and that rather roasted than boiled, a good fire, but little drink, especially of small liquors, are necessary to health; and as a medicinal preservative, nothing is equal to the bark for keeping up the vigour of the blood, and securing it from the whole tribe of intermittents. If the blood is liable to become viscid by too dry an air, succulent meats, mild diluting liquors, milk diet, and laborious exercise, are necessary to make the blood circulate. If the blood is become ha-

bitually viscid, the free use of malt liquor is to be avoided; and the science of physic hath as yet provided no remedy which is sufficient of itself, without lessening the quantity of the blood, and making more room in the vessels for a free circulation. Perhaps the remedy may be found at last in a vegetable diet, of a proper kind, with a prudent use of the warm bath.

Against the effects of extreme cold, the first rational preservative which common sense dictates is warm cloathing; and to secure the inside, a draught of oil is used by the Samojedes and Laplanders, and is the most effectual for the purpose of any liquor in the world. As to spirituous liquors, I believe a draught of cold water, as a security against the weather, is better. It is remarked that whales, aud all other fish of the northern seas, abound with oil to keep off the cold, and keep up the animal warmth; for those fish that abound with fat, have warm entrails, and many blood-vessels, which give them a nearer alliance to land animals. When cold hath touched the limbs so as to endanger a mortification, it is pernicious to come near a fire, because it occasions too sudden a resolution of the rigid parts, and destroys the finer

finer blood-vessels; as a frozen clod of earth is melted into atoms by a thaw.

In the heats of the southern climates, people find their strength exhausted, and are apt to recruit it by drinking copiously of wines and strong liquors. They are tempted also to great excess by the delicious cooling fruits of the Indies; the immoderate use of which is sure to bring on fevers and fluxes, which carry off numbers of indiscreet people, who either through ignorance or appetite will not deny themselves. Temperance is the best security, with the use of small liquors; and they must be careful above all things to avoid the evening dews and nocturnal colds, in those tempting climates, which bring on spasmodic disorders, and sudden deaths, with such symptoms as are not known in this latitude. The unwholesome damps of the night, so mortal in the West Indian islands, when added to the many charms by which those places delight the eye and tempt the appetites of strangers, render them exact and instructive emblems of all those vices, which are pleasant in the prospect, but fatal in the trial. Every enchantress who tempts mankind to their destruction should have her residence, like Circe, upon a beautiful island.

As the body is very apt to be affected with

extremes,

extremes, and to perceive the one more sensibly for having been accustomed to the other, we should conclude that a person who has lived some years in the East Indies, should suffer terribly upon his return to England: but I was assured that the contrary is the case, by a worthy and intelligent gentleman who lived twenty years in China*. For the first winter after his return, he continued the use of his linen and silken cloathing without any inconvenience; and has observed many other gentlemen from the same climate do the like: but this is only during the first winter; afterwards they find the necessity of relapsing into the woollen winter cloathing of this country†.

The situation of places, and the weather to which they are subject, should be well understood, for the preservation of health. The worst situation of all is one upon a level with such flats and marshes as are overflowed by the sea. Where the salt water has stagnated, the

* Mr. Flint of Jud-house, near Feversham in Kent; the gentleman who is mentioned in Anson's Voyage, book iii. c. 10.

† Since this was written, I have heard the same confirmed by many others on their own experience. And they add, that the heat of the Indies does not generally affect the constitutions of Englishmen, till they have remained there two or three years.

the air becomes putrid, and the sun raises such fogs and damps as are of all others most injurious to the human constitution. Some endeavour to secure themselves by spirituous liquors: but woe be to them if the enemy gets within their fortifications; for then they are in more danger than ever, and their *last state is worse than the first,* like that of the man who had an *evil spirit* within him. The daily use of cold-bathing in the sea, is the best of all preservatives against the noxious air of the sea-marshes. I was assured, upon the authority of a clergyman then resident in the place, that when a party of horse were quartered at the worst point of land in the hundreds of Essex, the wives of the soldiers, who were chiefly from Scotland, made it their practice to dip their young children in the sea every day; and it was found that those were more free from agues than the children of the natives. This is a very extraordinary fact, which may be applied to the preservation of the soldiery when they are sent on expeditions in the air of foreign climates, where there are unwholesome low-lands adjoining to the sea; against the ill effects of which, the sea itself is the best remedy in the world.

The next bad situation is near stagnant pools

pools and marshes of fresh water; where multitudes are carried off by intermittents, and as many more by intemperance, into which they reason themselves, by yielding to a very false and corrupt philosophy. Too many trees and woods are unwholesome, because they are productive of so much rain and vapour; and a naked soil where there are downs, plains or heaths, is too dry. The exhalations that arise from woods, if not of too great extent, are salutary and serviceable to the air. Animal bodies sink and die under a putrid atmosphere, but trees and vegetables correct it; therefore plantation is always to be encouraged to a proper degree. Flats near the sea are rendered more unwholesome, because there are no trees to correct the noxious vapours: and it is suspected, with good reason, that the city of Rome is so very unhealthy in the autumn, because the country all about it is so naked, with no trees to qualify the putridity which is generated by the preceding heats of the summer. It is probable the great verdure, with which the cultivated country of Egypt is so soon covered universally after the retreat of the Nile, prevents any ill effect upon the air, or prevails in due time to correct it. Hills are necessary to give shelter, with a more advantageous exposure; and they

 yield

yield running springs and rivers, which are not only necessary to the immediate support of life, but create fresh air, prevent stagnation, and correct occasional putridity.

In the different kinds of soil there are two extremes, both of which are very bad; the one is a loose barren sand, and the other a bottomless clay. The happiest situation I can describe, and the most promising toward the enjoyment of life and health, and every convenience, is near the bottom of an high hill that hath a southerly exposure, with woods and plantations about the head of it; a dry soil of sand or gravel, with a mixture of loam, and running waters, with green meadows, before it; or the sea, with a steep and clean shore of gravel or beach. There may Health fix her seat; but let no man think that his situation will preserve him, unless he has the prudence to preserve himself. All the varieties of the weather, all climates, all the seasons, and all the elements, are at war with the indolent and the intemperate.

END OF THE PHYSIOLOGICAL DISQUISITIONS.

SIX LETTERS

ON

ELECTRICITY.

LETTER I.

Dear Sir,

In the natural world, a scene so new and extensive has been opened by the late Discoveries in Electricity, that it is not easy to assign a reason why they have been so little applied in Philosophy. The leading facts in this science rose up at a strange time and in a strange manner, as if they were intended to be of great use to the world; which use hath not yet appeared, though the science hath been in the hands of very ingenious men. Of the time at which Electricity was discovered, I say nothing as yet, though it was very remarkable: the manner I can relate to you nearly as I received it thirty years ago from an intimate and respectable friend, who was a party concerned in

the discovery, the late Reverend Granville Wheler, of Otterden Place, in Kent*.

There was an ingenious man, Mr. Stephen Grey, a pensioner of the Charterhouse, who delighted much in experiments. It was the practice, at that time, to rub a large tube of glass for attracting threads and other light bodies; and Mr. Grey, having found that his tube would not act well but when perfectly clean and free from dust, stopped the open end of it with a cork. One day, when he had rubbed his tube, and applied a thread to different parts of it, he observed that the thread went to the cork at the end as readily as to the glass of the tube. This taught him that the power of Electricity was communicable from glass to other bodies. The steps he made, in consequence of this, were easy and natural. Instead of the cork, he fixed into his tube the joint of a fishing-rod, and discovered the same power to the end of it. At last he tried his whole fishing-rod, with a line of packthread and an ivory ball at the end

* He was commonly called by the name of the Reverend Granville Wheler, Esquire, and is addressed under this title by the ingenious Mr. Benjamin Wilson, who dedicated his Treatise on Electricity to him. He was the son of Sir George Wheler, Knight.

end of it, from an upper window; when the ball at the end was still found to attract light bodies as before. With this discovery he went full fraught to his patron, Mr. Wheler, in the country, and repeated every thing with success as far as he had gone. But they determined to go farther; and for this purpose repaired to a long gallery above stairs, which encompassed three sides of the house *; and having extended their line, the length of which required that there should be loops from the cieling to support it, they tried the effect; but now there was no answer, and they were quite at a stand. But it so fell out, that they blundered upon a true method in consequence of their own false reasoning. These loops of ours, said they, are too thick and too heavy, (for, by the way, they had made a trial of iron wires;) our way will be to make the loops of the strongest line we can get, with the least weight and substance. On this consideration they gave the preference to sewing silk; and now all was right at once; but they still argued, that their success was owing to the smallness of their lines, not to the silk of

* This ancient seat, which had an observatory at the top of it, has been pulled down to the ground for some years.

which they were made. A few more experiments taught them to correct the mistake; and they discovered, that there were bodies of different constitutions, some of which would stop the power, while others would let it pass off freely and be dissipated; these we now call *conductors.* Thus the great distinction was opened between Electrics and Non-electrics. But every thing came out by accident: for Mr. Wheler assured me, that neither he nor Stephen Grey had ever reasoned right in any one instance that he could remember; so contrary were the effects of Electricity to all the pre-conceived notions of philosophers.

Mr. Hauksbee, an ingenious operator to the Royal Society at the beginning of this century, invented a method of increasing the power of glass, by mounting a globe so as to be turned by a wheel; and a globe being so contrived as to be capable of being exhausted of its air upon an air pump, the electric fluid began to display itself in a wonderful manner. Opaque bodies, when illuminated by it within the globe, became transparent; for when the inner surface of the glass was coated with pitch or sealing-wax, the hand of the operator, which rubbed the globe,

globe, became visible through each of these substances.

Both Hauksbee and Grey shewed a disposition very early to speculate upon their new experiments, as if they had discovered in them some alliance with the great moving powers in the system of the world. Grey was delighted with the prospect: but in the application of his experiments he was rather too hasty, and his haste made him inaccurate; of which the philosophers of the time, who had then lately set their whole affections upon a *vacuum*, took advantage, to render his speculations inconsiderable: and with many practitioners the electric medium still kept the name of an *effluvium*; as if it had been emitted wholly by the glass, and were of little more account in the world than a common odour.

In a short time it came to pass, by another singular accident, more remarkable than that which had happened to Stephen Grey, that Muschenbroek of Leyden discovered a new force, of which, from that time to this, it has troubled the learned to give any rational account; opinions being even now in agitation concerning it, which are in direct opposition to each other. Electricity had hitherto

appeared as a simple direct force, which could make its way through iron as easily as through a vacuum. But now there came upon the stage a new force, which we may call *reverberatory*; because the fluid, instead of flying off forwards, as in common cases, is arrested, retained, accumulated, and flies back again with a great stroke and an explosive noise. Muschenbroek had suspended a glass phial of water at his conductor, and was electrifying it to try how long the water inclosed by the glass would retain its electricity: but, in doing this, he grasped the bottle with one hand to remove it, while his other hand touched the conductor, and in this instant he received a stroke through his arms and breast, attended with such a sensation as no man had ever felt before, and which he that has once felt will never forget. This was a wonderful fact; and as soon as Muschenbroek had made himself master of it, he reported it. The fame and the practice of it soon flew into every civilized part of the world. People of both sexes, and of all ages and conditions, repaired in crouds to see and receive this wonderful shock; and the public curiosity was so much awakened, that every body was ready to hear what writers had to say

say upon the subject. Dr. Watson, a physician, gained great reputation by his manner of treating it, and I heard several learned persons pronounce his work to be the best that appeared upon the occasion. He made no scruple to call the new power of electricity by the name of *Elementary Fire,* and his electrical machine a *Fire-pump.*

It is something remarkable, that from the earliest days, when excited amber and glass were first observed to crackle and flash in the dark, an alliance was suspected between this light and the lightning from the clouds: and, in process of time, when the matter came to a trial, this alliance was no longer doubtful. Which of the two was first in bringing down fire from Heaven; whether Romas of France, or Franklin of America, has not been well ascertained, so far as I have been able to learn: but let it be Dr. Franklin; for then the fact will be an ominous prelude to the business he was soon afterwards to do in the world, in drawing down the fire of civil war upon his country, and spreading the confusion of anarchy over the earth. The Frenchman may certainly put in his claim; for the omen will agree as well with his present national character: but we

need not trouble ourselves in settling their respective shares: they have it all between them; there being no others who have so just a title as the American and the Frenchman to be called the incendiaries of the world.

Philosophical men became so fond of this new art, whereby a thunder-cloud was turned into an electrical machine, that the practice became common—I think, rather too common, in many places. A poor professor of Petersburgh was at this work, when a ball of fire came suddenly down from a cloud into his machine; and he being the nearest object to his conductor, received the stroke upon his forehead, and was killed upon the spot. When I read of this fatal accident, my mind is shocked with it, and I am reminded of that day when the boldest philosopher shall discover, with this unfortunate professor, that Heaven is not to be trifled with. But Dr. Priestley discovers him to have been a very fine man, and that he died a very fine death, such as other philosophers might envy and desire. His notions and mine differ very greatly on many subjects; and his reflection on this occasion must arise from some new theory of life and death, worthy of Dr. Priestley.

The

The relation between Lightning and the Electric Fluid being established, it was inferred that lightning might be collected and dissipated without mischief; and no house was thought to be secure without a conductor upon the top of it. But the case is attended with difficulties, as time hath shewed; and the argument in favour of knobs against points is a sufficient proof of it. At first the whole dependence was upon the effect of sharp points, to draw off the matter of lightning by a silent discharge. But points having miscarried in the case of the powder magazine at Purfleet, there arose a serious dispute in favour of the ball or knob against the point, it being objected that the point was more apt to invite the flash, and less apt to disperse it. I am not clear how this ought to be; and I question much whether we are competent to the stating of it. This I know, that from the beginning I never was very sanguine in favour of the conducting plan. The following accident discouraged me very early. I knew a place in the country, where there is a high steeple of stone, with an iron spindle and weathercock at the top; but when a storm of thunder came over, the lightning struck a low house not far from the church, which

which house it burnt to the ground, and killed some people within it; while the church, a much higher building, was untouched. This taught me, that the conducting principle was not to be depended upon, if a high-pointed building near at hand had proved no security to a low one. I knew of two houses afterwards which were struck while they had conductors of iron upon them. There were not wanting persons, on this occasion, who argued as if they had found out that the conductors had not acted properly on account of some defect; but these things served to convince me, that there were dangerous difficulties in the way; that conductors did not act quite according to the theory, or that their effect, whatever it may be, extends but to small distances; that in certain cases they may even be attended with danger. What escapes St. Paul's church and the magazine at Purfleet may have had from the lightning itself, we know not, but we have much reason to believe that they have had two escapes from conductors; and, on these considerations, it has appeared to me of late years as a matter of no great consequence to *inoculate* buildings against lightning. It is a good thing if we can lessen the danger of ships at sea

sea by it, and we may be thankful for the discovery.

Since this invention of drawing fire from heaven, improvements have consisted chiefly in playing new tricks, and diversifying old experiments, and observing how minutely various the states of bodies, and of the atmosphere with its meteors, are in respect of their electrical affections. Here the science is without end. How much more easy it is to multiply than to simplify! When old things appear to us under a new shape, we give them new names; and when we get new names, we think we get new knowledge. Hence hath arisen a vain expectation, that if we do but wait long enough, experiments may be increased, till it will be time to raise a theory: but that time, I fear, will never come; so far as the purpose of a theory is concerned, materials are very nearly in the same state now as they were fifty years ago, and we are now most certainly in a state to do something if there is any thing to be done. Our information has proceeded from a quarter whence we had very little reason to expect it. Electricity, so called from *Electrum*, *Amber*, began with moving a straw; but hath now shewed itself powerful enough to move the

world, and, being such, it is entitled to some great share in the economy of it. If it acts for *evil*, as in lightning, it has the same ability to act for *good*; and for great good the Creator undoubtedly intended it. Such observations as I have made, with a view to discover this, I shall freely impart to you; and I think I have already said enough in this letter to raise your curiosity. If Pliny, the natural historian, had been told that there was a man in Britain who could send a strong spark of fire out of brass into another man's forehead, which should strike without burning, and come out instantly at his toe, he would not have rested till he had learned all that could be known of the secret. Such a wonder as this has been reserved to our days; and now we have it, you will think as I do, that if we can, we ought to make some use of it in our philosophy. With this design I shall take the liberty of addressing some future letters to you. And am,

With sincere affection,

Your very faithful humble servant,

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Jan. 3, 1797.

LETTER

LETTER II.

SIR,

AFTER the general view of things which I gave you in my former letter, we must now descend to particulars, and ask, *What* it is that *acts* in Electricity? This is the first question which any curious person will ask, who has heard there is such a thing as Electricity, and seen some of its wonderful effects. And here, instead of giving you a short answer, I shall set before you some plain facts, which will be sufficient to prove that the causes which act in Electricity are not new, but very common and familiar to us; and that we cannot deny them without denying our senses.

When a person electrified presents the point of a sword to you, you feel a blast of air from it very sensibly; and to convince yourself that this is no deception, let a bason of water be placed upon the ground, and let the

the point of the electrified sword be presented downwards near to the surface of the water, the blast from the point will make a dint in the surface; and the same being directed toward the flame of a small lighted taper, will blow it out. If any doubt should yet remain, (for some plain things require a great deal of proving,) let us appeal to the air-pump. Place a vessel of water under a glass receiver, and point an electrified wire toward the surface of the water as before, the dint on the surface will appear as it did from the sword; but exhaust the air, and the point will now make no visible impression. Therefore that impression was made by the matter we have exhausted; and that matter being air, it appears that air is an agent in our electrical experiments. It is farther worthy of observation, that light bodies, which are attracted while the air is in the receiver, are not attracted in vacuo; for hence it must appear, that whatever the manner may be, after which the air may act or be acted upon, it is necessary to the effect. This was observed and affirmed by one of the first operators in the science, an ingenious man to whom we are under great obligations, I mean Mr. Hauksbee. He was of opinion, that, in the

the case of an attrited globe or tube, "the "external air is necessary to *carry* the little "bodies which *we say are attracted* towards "the tube. For if by the heat and rarefac-"tion consequent upon the attrition, the "medium contiguous to the tube be made "specifically lighter; then, of course, to keep "up the balance, the remoter air, which is "denser, must press in towards the tube, and "carry away the little bodies lying in its "way thither also*." Dr. Priestley wrote a a ponderous book, which he calls an History of Electricity; but he is not a man from whom we should expect either a fair account or a judicious performance. He pretends to give an account (and a confused one it is) of Hauksbee and his experiments; but says not a word of this his idea of electric attraction. Priestley's book appears to have been compiled with a factious intention, which tempted him to suppress, or magnify, or depreciate as he should find occasion; that he might keep the science as much as possible within the few hands of himself and his party. Mr. Hauksbee's was a rational conjecture for the time, and near the truth, but not quite accurate. Electric attraction is still a subtile phæno-

* See his Experiments, p. 244.

phænomenon, which will be imperfectly understood after all our trials. I can see that more are wanting even at this time of day; and there is one circumstance relating to it, which is very remarkable: that although the power of Electricity be an *effusion*, working *outwards* from the machine, the *first* motion of bodies is *inwards* toward the machine, they being universally attracted before they are repelled; which being a fact of great consideration, I shall have something particular to say upon it in another place.

Experiments teach us farther, that the electric Fluid is the same with that which gives *heat* to bodies. Of this I was once in some doubt, having found that a thermometer was not affected by its motion; whence I supposed that a fusion of metal by electric force might be a cold fusion, as had been reported of fusions by lightning. I therefore desired a friend, whose apparatus was very complete, the late ingenious Mr. Henley, F. R. S. to shew me the capital experiment for this purpose by exploding a small wire, and catching some of the liquified sparks upon a sheet of writing paper, which he did accordingly; and a very fine shower of fire flew about the room, the sparks of which appeared

peared to have scorched the paper in several places, as any other fire would have done. We now understand, that when the electric fluid is *compressed*, by being forced through too small a channel, it then acts as fire: bodies are violently *heated* by it, and even melted with a burning fusion, as we see in this experiment of the exploded wire. A mercurial thermometer also, though not sensibly affected by being electrified in the ordinary way, (which was the occasion of my mistake,) may be made to rise thirty degrees, if the shock is made to pass through it after the manner described by the late ingenious Mr. George Adams: see his Lectures, vol. iv. p. 390. It is certain, then, that the electric fluid gives heat; that it will fire tinder, light a candle, kindle gunpowder, &c. Some philosophers have long supposed, that motion is the cause of heat; so it is, but this happens only because fire is moved. The heat which arises to solid bodies is not immediate in themselves, but in the matter which penetrates and acts within them. This the electric fluid being able to do, is occasionally excited to the condition of heat, and is therefore one of the modes of fire. That which has the properties and effects of fire, should

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be called fire, when we speak of it as a fluid; otherwise we shall have two things in nature, with the same properties, and to serve the same ends, which is by no means agreeable to sound philosophy. It is now time that the late doctrine about fire, which taught that fire is nothing in itself, but that the parts of solid bodies in motion are called fire, should be laid aside, as obscure, unphilosophical, and contrary to experience. I have often wondered at the disposition which has discovered itself in mathematicians of modern days, to annihilate fire, and turn it into *motion;* though it be without question the universal fluid of the world. Galilæo argued, that it was *hitherto doubtful whether there be any such element as fire**.

Instead of producing so many facts to shew that the electric fluid is fire, I might have contented myself with referring you to the many authentic accounts, which assure us, that the fire of lightning and the fire of electricity are the same, and may be substituted the one for the other; for in that case we have nothing to do, but to prove that lightning is fire: and did any body ever doubt

* Dico primum, esse dubium adhuc, an sit Elementum aliquod Ignis. Op. 1635, p. 437.

doubt it? By an aerial conductor we can take it out of a cloud, and perform the same experiments as when it is excited in the ordinary way by attrition of glass. What we take up in a drinking glass from the ocean is not more surely the matter of water, than what we take out of a thunder-cloud is the matter of fire.

It must have been observed farther, for we cannot help seeing it, that the electric fluid is luminous and shines as light, the same with that of the sun or a lighted candle. And here again it would be as unphilosophical to allow of two sorts of light in the creation, as two sorts of fire. But I may convince you by an experiment, that the electric fluid is not only a luminous body, but that it is really and truly the body of light, such as we have always been used to, because it has that property which is characteristic of light. By the refraction of a glass prism, the rays of the sun are separated into seven colours; three of them primary or simple, and four compound. From which I thus argue; that if the light from the sun is thus separable into colours, and the light of electricity is separable into the same, we are to

conclude they are both of the same matter. The experiment is made in the following manner: We present a non-electric to the conductor within less than the striking distance; in which case a succession of sparks will succeed one another, so quick that they appear to the eye like one continuous line. View this through a prism of glass, and you will see the same coloured spectrum as if the rays of the sun had formed the object*. Therefore the solar light, and the electric, however they may shew themselves, are the same in kind, as surely as the noise of thunder is the same in kind with the noise of the Leyden bottle. After this it is hardly worth while to mention, that if you hold up a leaf of gold between your eye and the window, the rays which pass through it are green; and the sparks drawn from gold have the same appearance.

If these things are so, let us agree, that the light which electricity exhibits, is not a new composition, but the old light, which has flowed from the sun, and flashed in the heavens,

* This experiment was published by Dr. Priestley as an original experiment of his own, though it had been published several years before.

vens, and shone in the rainbow from the beginning of the world; and that if it be compared with lightning, it has the same effects and the same appearances. As the sun which now shines in the heavens, is the old sun which shone upon our forefathers, so is the light which now shines in electricity the old light; and we shall not be able to change its nature by putting some new name upon it: its mode of acting is indeed newly known to us, and well deserves to be studied. The wise men of France have put new names upon the days and the seasons; but, God knows, they have mended neither the times nor themselves. They have divided the month into three decads, instead of four sabbaths: but the moon has her four quarters as she had formerly, and will have them to the end of the world. No whole number will divide her monthly period so truly and properly as the number 7; and they who would change it for a better, should give us a new arithmetic; which, among the rest of their extravagancies, I wonder they have not attempted.

I have now answered the question I proposed at the beginning of this letter; and

shewed you that the power, which acts in electricity, *blows*, and *burns*, and *shines*: let any man prove, if he can, that it does not. With this, for the present, you will be satisfied; and believe me, dear Sir,

Affectionately yours, &c.

Jan. 6, 1797.

LETTER

LETTER III.

SIR,

THE design of my last letter was to shew *what* it is that acts in electricity: I am now to proceed a step farther, and inquire *how* it acts. You have seen, that, how various soever effects may be, (of which there is no end,) the causes are such as have always been known. They appear to us under a new character, but they are still the same. We might disguise them by giving them new names; but real knowledge would thereby be rather confounded than improved. When a ship is blown up, you may tell me it is *gunpowder* that does it; and that gunpowder is a composition found out in modern times, and composed of certain ingredients in such and such proportions. But I say, no: I say the ship is blown up by a flash of *fire* and a blast of *air;* and that gunpowder is no more than the *vehicle* in which these powers act. This

is a solution of less shew and verbosity: it is embellished neither with *oxygene* nor *caloric*, nor any other term borrowed from the mysterious vocabulary of the new *Capnology;* but it declares, in old terms, the whole secret at once, and is agreeable to truth and fact: as such I am content with it. If you please, you may fill a book with receipts for making, and directions for kindling, and rules for applying the force of gunpowder; and for so doing, I will allow you to be an expert man, and that you instruct us farther in the works of art: but you go no farther into the *causes of Nature* than I do. Their action under the form of gunpowder, and their action upon the stage of electricity, is such as the world was not formerly acquainted with. They did not foresee, that art would so nearly imitate the force of a volcano, and the action of a thunder-cloud.

But we are now proceeding to a part of the subject, which will oblige me to take a large compass; for when we inquire *how* these causes act, we have a wide field before us, where nothing is to be explained, unless the following doctrine be admitted as a foundation; that in all free spaces, and within the pores of all bodies, whether solid or fluid,

there exists a subtile æther or elementary fire, which, while at rest in equilibrio, seems to be doing nothing, but is at the same time silently at work in all nature. Till it is disturbed, or thrown out of its balance, it does not shew itself; and even then, we know it not in its *total* force, but only in its accidental *differences;* for its total force is such that, unless it were counterbalanced, it would crush the world.

If there be two equal scales, each of which carry a weight of 100lb. they are at rest: but if you place the weight of half a pound in either of the scales, the one goes down, the other up, but only with this force of half a pound; and if we should conclude this to be their whole force, we should be greatly mistaken. It is thus with the forces of electricity: we discover them in their differences; but even these on certain occasions are such as are attended with great effects. How these differences are made to appear, I shall explain to you on the principle I have already laid down.

In that ocean of invisible elementary fire wherein we live and move, we place a machine, and turn a globe or cylinder of glass. When the glass is turned about, the element,

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in which it revolves, follows it; as when a grindstone turns in a trough of water; and so long as the revolution of the fluid is uninterrupted, nothing is done; whence we might ignorantly conclude, that the glass revolves in nothing. But if we apply a cushion to the surface of the glass, and make a stoppage or dam, the medium, which could before flow freely, is now separated into two conditions, and consequently put out of its natural state. Part of it can pass the cushion, and part of it cannot. To the cavity within the glass none of it can escape; because glass is a substance through which it cannot pass freely, being partly hindered by the air incumbent on the inner surface of the glass, and partly by the structure of the glass itself, which is of such a constitution as not to admit it. The fluid therefore which surrounds the glass and moves with it, cannot be as it was before: it is stopt by the close contact of the cushion, and as it were *strained* into a new state; I say strained, for I believe this circumstance to be a chief part of the secret. When Electricity first came into observation, it was natural to imagine, that the effect was excited by an *attrition* of the rubber upon the surface of the glass, either working upon the *air*, or putting

putting the parts of the glass into an unusual agitation, so as to make them *emit effluvia*, &c. But farther experience shewed another thing: for if the separation takes place, the attrition is of little consequence. A rubber of a proper length, though it were but a line in breadth, would answer the purpose, provided the contact between that and the glass be as perfect as possible; which is greatly promoted by rubbing over it an amalgama, or mixture of zinc and quicksilver about the consistence of an unguent; or some *aurum musivum* may be used; than which nothing can apply more closely to the smooth surface of the glass, as is found by long experience.

But now there comes before us a circumstance equally certain and extraordinary; for as soon as the separation commences at the cushion, there commences with it an *indraught* of the same fluid; which must be supplied through some channel, which forms a communication between the cushion and the body of the earth. A communication with the atmosphere is not sufficient: there must be a communication with some non-electric body; and that body must communicate with the earth itself, which, on account

of

of its magnitude, can furnish a constant supply, without suffering any sensible alteration in itself: so the fluid comes freely from thence through the pores of any non-electric, in quantity sufficient for all our purposes, and at all times, as from an inexhaustible promptuary. In a word, it comes from the world to the machine, not from the machine to the world, as was at first imagined. To prevent the electric flux from being dissipated after it has passed the cushion, a skirt or flap of prepared silk is added to the cushion, which covers the glass more or less according to its size; and in this form an electric machine will do its work, but never so completely as when all is perfectly clean and dry, and *warm from the fire.* The fluid thus collected and in motion will make its way into all non-electrics near enough to receive it, and be equably diffused through their whole dimension at once. Into the air, when dry, it will not evaporate, but by degrees and slowly: for the pressure of the atmosphere is the antagonistic power which concentrates and confines electrical, as it does common fire: and this pressure will have its effect in keeping in the electric fire, though a bar of iron be red hot, nearly the same as if it were cold. Let a bar of

of iron be made red hot only in the middle, we shall find that the electric fluid will pass from end to end without interruption. This does not prove that fire and the electric medium are two things, but only that they are two different modes of the same thing, as wind and sound are two modes of air, which give no interruption to one another. The effect of the atmospherical pressure is greatest when the air is dry: but if it be totally withdrawn, the electric matter which is communicated flies off, for the same reason, as an heated body grows cool sooner in vacuo; air being in all cases the antagonistic power to fire. This is the reason why the matter flies off so easily from a sharp point; the pressure of the air being little or nothing upon it: but the form in which it goes off is worth observing. It is that of a cone or brush; which cone is always attended with a blast of air, in a direction from the point outwards; which direction in the air, must denote the same direction in the cause. For this reason, *a blowing point* is always supposed to *give*, while a receiving point is marked with a small star, or luminous ball, upon the end of it.

The escape of the electric matter in vacuo is attended with this curious circumstance, that

that instead of diverging, as when the point blows in air, it goes right forward in a line. This it never would do, if the parts of the fluid were endued with any quality of repelling each other, to which the elasticity of a fluid is commonly ascribed: for if it were what we term elastic, it would shew itself to be so when it is most at liberty.

It is a great entertainment to observe, how powerfully the internal parts of glass are affected, when the electric spark is *repeatedly* applied to them. Let a thin receiver of glass of some length be well exhausted of its air; then let the spark be repeatedly directed to one point of its superficies; after which, if it be removed into the dark, it will be seen to flash of itself by intervals for a considerable time, as if the parts of the glass had been disturbed in their natural situation, (as they certainly had,) and required some time to recover of their vibrations; in doing which they sometimes fly to pieces. When these compound experiments of the higher class are repeated, they will not always be found to answer, by reason of some slight differences in the apparatus of different persons; but the ramifications of light, which play withinside an exhausted glass when its outside is electrified,

trified, are commonly known, and are extremely beautiful.

Great pains have been taken to measure the velocity with which this fluid passes through the internal substance of bodies: but that question could never be resolved; and it has been pronounced instantaneous. And there is a remarkable circumstance, in which electricians were formerly well agreed; that its force is rather increased than diminished when it passes to a distance; which could not possibly happen if this matter were affected by a *vis inertiæ*, either in itself, or in other bodies. It certainly flies upwards or downwards, to the right or to the left, with equal force and velocity. A matter of such force, acting according to no known laws of gravity, projection, or attraction, is a new phænomenon in the regions of natural philosophy, and must disturb people in some opinions wherein they have long rested: and on this consideration it is to be feared there are those among the learned to whom it hath not been a very welcome guest.

When I say that the electric fluid is subject to no attraction, I do not mean to deny the fact, that, in electricity, bodies are, by some means or other, drawn towards one another;

ther; but I mean that the fluid is subject neither to attraction nor repulsion *in itself*. Repulsion has indeed been ascribed to it, as it also hath to the air; but I believe it to be neither in the one nor in the other, in the sense commonly intended; but that *apparent repulsion* is *occult extension*. If electric matter were actuated by any such power, it would discover itself most in vacuo, where we see nothing of it.

I am now coming to a part of our subject which has never been touched, so far as I can discover; and I have turned over some books with this view. It is an allowed law of nature, that, from any space which is filled with any medium, nothing will come out till something is ready at hand to take its place. This used to be called nature's *abhorrence of a vacuum*. When the electric medium flows from the conductor of a machine, some other matter must have access to it, without which the efflux can neither begin nor continue. It has been a question with me, in which of these two the motion begins; or whether it begins in both at once, as when the opposite sides of a wheel begin to move in contrary directions at the same instant. From what appears, the first impulse is *toward* the machine; and I

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was induced to think so by the followi g experiment.

The jet of water, which springs from an artificial fountain, is observed to take three different forms. When left to itself, it ascends in a small column till, toward the top, it breaks into sprigs or drops, which diverge a little and fall to the ground; this I call its first or *natural* form. When it is electrified, the sprigs begin to diverge near the bottom of the column; and may be made to spread themselves over the room, much after the form of a weeping willow: and the whole field of natural philosophy scarcely affords a more beautiful spectacle: I call it the electrical *Tree.* This is the second form. But there is yet a third, different from both. For if the wheel of the machine be stirred very gently, so as to render the power perceptible in its beginning, it is then seen that the first impression is *from without*: for the jet, instead of diverging at the top after its own natural way, shrinks back upon itself, and resembles the head of a club. This is an easy and sure experiment, which never fails if the wheel be gently moved at first: and it speaks to us a language of great importance; for from hence we learn, that the power of electricity is in-

wards before it is outwards: and farther, that as the two artificial forms are two *states of electricity*; so is the common or intermediate form a state of electricity; the natural state; in the producing of which we have no share: and if so, the natural state of the world is a state of electricity; that is, the electric element is silently and constantly regulating the motions of nature, whether we observe it or not.

Being desirous of seeing this order of the powers in electricity farther confirmed, I made the two following experiments: I fixed a pointed wire to the conductor, and held another point directed to the conductor in my hand. It was always observed, that the point in my hand shewed its light first. It is scarcely necessary to add, that this must be done in the dark. When bits of light paper were placed, one on the conductor, and the other on a stand, two or three inches below the conductor, and the wheel was *gently* moved as in the experiment of the fountain, the paper on the stand always flew toward the conductor before the other flew from it. But, after all, what need is there of this trouble? for does not every spectator see that light bodies are always attracted before

fore they are repelled? whence it is evident that attraction is first in order.

While I have been thus inquiring which is first in order, the afflux or the efflux; hypothesis denies that there is any afflux at all; affirming that it is all efflux. The Abbe Nollet persisted in the doctrine of an afflux; for which Priestley paid very little regard to his authority. Dr. Watson saw the reasonableness of it very early, and took great pains to prove it. He suspended upon silk lines both the machine and the man whose hand excited the globe; which cut off all communication with the earth: and in this situation the man and the machine produced little or nothing. But when a person standing on the ground touched the conductor with his hand, the man at the globe yielded sparks. This proves that the machine is without a supply, till it is furnished by the person who stands upon the ground. What he furnishes comes in a direction toward the conductor; and this is what we mean by an afflux. How it came to pass (if it really did come to pass) that Dr. Watson, when he had demonstrated this principle, did not keep fast hold of it, is more than I can explain: but, according to Dr. Priestley's account of

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things, he gave it up. Men are struck with facts at their first appearance, and they speak a plain language about them: but when hypothesis comes in, and fashion gathers strength, they change their opinions. To me this experiment either proves an afflux, or it proves that there is little use in recurring to experiments for information; and that experimental philosophy may be as uncertain as any other. The experiment of Dr. Watson is really nothing but the common experiment reversed. In the ordinary way, a person stands upon the ground; he rubs the glass; and sparks are taken from the conductor. In Dr. Watson's way, the man, suspended on silk lines, has the place of the conductor; and so every common experiment proves the same with the operose experiment of Dr. Watson.

Before I can attempt to explain the double force, or shock of electricity, I must lay down some preliminary observations. The matter of electricity is differently received by bodies of different constitutions, which we distinguish into electrics and non-electrics. In the former class are amber, glass, rosin, pitch, &c. and these are held to be impenetrable by the electric medium. The non-

non-electrics are metals, water, linen, &c. which give it a free passage; and are therefore denominated conducting bodies, or conductors. In its degree this distinction is true; but it is subject to *conditions:* for electrics become conductors, when we change their condition in respect of heat and cold. Glass, when red hot, gives a free passage to electric fire, as other bodies do; its constitution being then relaxed, and its pores more open; which is the best reason we can give. I say, then, that glass, which can become totally penetrable, is never totally impenetrable, but more or less so according to the state of the fluid inclosed within it. The electric fluid can resist itself, though it is not resisted by other bodies; therefore, what happens to it is not to be imputed to the bodies, but to the condition of the medium within them. I premise this, because it is necessary to a solution of the Leyden experiment, or what is called the shock. This shock happens when an equilibrium, which had been interrupted, is suddenly restored. That an equilibrium is *restored,* nobody will wonder, because it is the effort of nature to preserve it. But how is it *interrupted?* Here

lies the whole difficulty. I find, then, that glass, commonly supposed to be totally impenetrable, can be so only to a certain degree. That the fluid passes it with difficulty is certain; but when it has done this, the two sides of the glass are in two different conditions: the medium is divided into its two constituent parts; which parts are by nature always mixed together in due (and perhaps in equal) proportion. These two will not part without difficulty, and under particular circumstances; and as soon as the way is open, they will unite again with violence; which violence is more or less according to the difference which had taken place between them.

Two different powers in electricity are so manifest, that as to the fact itself we shall meet with no opposition; but in defining the fact, people differ very much. Some call these powers more or less; positive and negative; vitreous and resinous: others are contented with calling them powers, and say they are contrary. Two *things* they certainly are not; for in kind both are the same; but they differ after a particular *manner*, of which our senses have not hitherto furnished us with

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an idea; and when we talk without ideas, words are but of little use. If we call the one A, and the other B, we shall explain as much as we know, without the danger of speaking falsely.

In a case nearly allied to this, I and all mankind are forced to be content with a knowledge of the *fact;* because a *reason* cannot be given. When the white rays of light are parted by a prism of glass, one extreme is *red,* the other *blue:* they are differently refrangible; they affect the eye with different powers; and when the glass is no longer interposed, they unite immediately, and become as they were before. Nature is here put out of its course by the *interposition of glass;* and discloses to us a wonderful and beautiful spectacle. But if any one should require me to define what and why these colours are, and how they came to unite so immediately after they had been separated, I am totally at a loss, and must rest myself upon the fact. The case is the same in electricity. The interposition of glass separates two powers, which we did not perceive before: but what they are in themselves, and in what respect they differ, who can tell? One of them may be derived upwards, from

the body of the earth, and be in its quality *terrestrial electricity;* the other may be derived from the sky, and be *celestial, aërial,* or *solar electricity:* but from whencesoever they may be derived, they part with difficulty, and unite with violence. This is sufficient for our purpose.

Let us say, then, that if across a current of electric æther, as it is conveyed from a machine, a square of thin glass be interposed, this æther is not absolutely stopt, but so checked as to be divided into its two powers; which are now resident on the different sides of the glass, and kept there by the pressure of the air: for if a vacuum be adjoining to the upper side, which I call A, the glass will not be charged. By the action of the machine on the glass, and the re-action of the glass on the machine, things are brought to this state. The experiment is commonly made with a bottle or jar of glass, coated on each side in such a manner that the sides cannot communicate: but whatever the form may be, the sense of the experiment is still the same. When a communication is made between the two sides, they *neutralize* each other, like *acid* and *alkali,* which meet with a similar commotion.

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Frequent inquiries have been made, to determine how these two powers meet; that is, which goes to the other, when the communication is open. Call the power next to the machine, which is commonly the uppermost side of the glass, A, and the opposite B; reason will assure us, that if there be an accumulation, it must be at A, where the force is directly applied, rather than at B; and that the equilibrium is restored in a direction from A to B. Yet arguments are brought to prove that they restore each other by a reciprocal motion; and that B does as truly move, in the article of the shock, towards A, as A towards B. But instead of pursuing this, I shall mention to you a curious fact; which shews that the two powers may change places, and the Leyden experiment may begin with B as well as with A: and if so, that neither of the powers can be *negative*, but that they are both *active*, and therefore both *positive*. Charge a Leyden bottle fully, with a chain hanging from the outer coating to the floor. When the bottle is charged as far as it will admit, unhook the chain from its bottom. The outside is then in the condition which is called *minus*: but from this minus, another bottle may be charged as the first was, and both in appearance will yield

yield a like explosion. This seems decisive against *plus* and *minus*.

The permeability of glass may be inferred, by comparing the different modes of performing the Leyden experiment. The same effect which is produced by the interposition of a plate of glass, may also be produced by the interposition of a plate of dry air, which is another electric body: but whether the experiment be made with glass or with air, the cases must be similar, and the principle one and the same. If so, the permeability of air will infer the permeability of glass *.

To compare and rectify all that has been advanced for and against the two powers in electricity, would be an endless labour: we should be bewildered and lost amidst a contrariety of words, facts and opinions. Two powers, call them what you will, (any thing but negative and positive,) are separated out of

* The Rev. Mr. Lyon, of Dover, asserted the premeability of glass, and produced an experiment to shew it. He discharged a Leyden phial, and completed the circuit through a plate of crown glass without breaking it. This the reader may see in the account he gave of his experiments. The authors of a periodical publication, the partizans of Drs. Franklin and Priestley, contradicted and misrepresented him in a very illiberal manner; and it is not in my power to settle their differences.

of the same medium, and do after their separation unite with violence: and when this is known, we have reason to be assured, that the same powers which do this, must do many other strange and important things in the natural world. I have little inclination to multiply terms after the number which this science has already brought into use: but it might perhaps be of some advantage if we were to call the stream first excited by the name of *single* electricity, and the shock from the two powers *double* electricity. Before I conclude this letter, I shall offer a few words on the *effects* of each.

By single electricity the electric motion of nature is increased, as the heat, natural to the atmosphere, is increased when we light a fire. When a person is electrified, the course of his blood is accelerated; when a plant is electrified, its vegetation is promoted: when a vessel of water is electrified, its evaporation is increased, like as when it is heated over a fire, but in a much smaller degree; consequently the perspiration of an animal body is promoted, for that is one species of evaporation. A leaf of gold may be suspended between two plates of metal; and in that situation it must be between two forces equally balanced.

balanced. Fragments of leaf gold, or other light bodies, may be even suspended in the air near to a conductor, and are sometimes observed to be whirled swiftly around it. This sight astonished Stephen Grey. He saw a disposition in bodies to revolve about an electric centre, and was transported with it; but could not reduce it to any thing regular. A downy feather electrified is extended in every fibre, as if it were a plant growing out of the earth in full vigour; but when the current of the fluid is withdrawn, it falls flaccid, as a plant does after it has been separated some time from the earth. The silent operation of this universal power in nature is permanent; it is at work day and night, though it must be subject to a fluctuation. It is not like the force of the wind, which comes and goes; it rises with a perpetual supply from the body of the earth. No man can doubt but that the same things which we do by art and violence, are constantly doing in the course of nature. What we do is like raising a sweat; what nature does is like insensible perspiration. Every moment must this power be working upwards from the earth; and having a passage through all vegetables, it gives them their erect position.

tion. And let me add, (for such is the order of nature,) that a current in one direction implies another current in the opposite direction, as the efflux in electricity is always attended with an afflux; and if I could not see it, I should reason myself into it by analogy, *a priori*. Even the skin of the human body is liable to absorption as well as to perspiration; and strange things are known to happen to us on this principle. In like manner, if the earth perspires, it must absorb; if there be a force acting upwards, there must be another acting downwards from the heavens, and this will account for the descent of roots into the earth. The two powers will be more particularly at work near to the surface of the earth, where their counteraction occasions that stubborn hardness and firmness which is found at the bottom of the trunks of trees, and the stems of more tender vegetables.

By simple electricity we are now possessed of a method of exhibiting that illustration of the celestial motions, to which Stephen Grey so much aspired without success. We can communicate electricity in such a form as to produce, in a spherical body, a *revolutionary* and a *rotatory* motion. The experiment

riment was first made by Mr. Rackstrow, an operator in Fleet Street, and excited much attention. The manner in which it is now best performed, is such as I shall describe to you.

A ball about the eighth of an inch in diameter, which for the sake of its levity is made of cork, is cut with a knife as nearly spherical as the eye can judge, and covered completely with a coat of sealing-wax or sulphur. This is turned to an exact sphere, and polished. A circular plate of metal very smooth at the edge is placed on a cake of wax or sulphur about half an inch in thickness, and laid on the transferring plate of an air-pump, so that the interval between the plate of metal and the rim of the transferring plate, may just allow room for the ball to move freely around. To the upper plate a chain depends from the conductor of a machine, and as soon as the plate is electrified, the ball begins to revolve, turning at the same time upon its axis, and continuing its revolutions so long as the machine acts upon it. The reason of the phænomenon is this. The ball is between two powers; it is both attracted and repelled; but being an electric body, it can receive the impression only on one

one point of its surface at once; which point being continually turned away, and a fresh point being presented, the result of this is a revolution and rotation. Mr. Grey pleased himself with having discovered, as he thought, a disposition in light bodies to move from east to west, like the planets; but that was a deception. This ball revolves either way, as it happens to take the first impulse: if stopt in its course, it will begin again as often as the operator pleases. I do not reason upon this fact at present, reserving that for another place. But I will mention, while it occurs to me, that in the presence of two learned gentlemen I made the globe revolve (as it did very freely) under a large receiver of an air-pump, from which the air being exhausted to twenty-seven inches, the globe would not stir.

The effects of double electricity, or what is commonly called the shock, are now so universally known, that there is little to be said which has not been said before. The convulsion it occasions in the muscles of the body through which it passes, can be understood only by those who have felt it; and even they are under a difficulty how to find words to describe it. I suppose the

fiercest beast upon earth might be terrified by it; and I have often wished to see it tried upon a lion or a tyger, or a furious unmanageable horse, it being very probable that the wildest horse might be broken by the proper use of it *. I had myself a dog, a beast of strength and spirit, but of great good humour, who having felt it a few times, would never after endure the sight of a common phial; but would fly at the person who held it towards him, though it were his own master: so lasting is the remembrance of the sensation. Now as the artificial or violent motion of the muscles is the natural motion of them increased, the cause of the violent is the same with the cause of the voluntary. Nothing seems wanting for this purpose but subtilty and power; and it has them both. Involuntary cramps and convulsions must surely be occasioned by the irregular and involuntary agitations of the same cause that produces the ordinary and voluntary motions. While its powers are balanced, we feel right, and are as if we felt nothing; but if the balance be interrupted on one side, we are sensible of a powerful agent, which gives us violent

* The shock was given to a horse at Vienna, who was unmanageable, and absolutely tamed him, by Dr. Ingenhouz.

violent pain. In the distemper called the *tetanus* and *opistotonus*, the contractions or extensions are violent and intolerable.

The two great meteorological examples of double electricity which nature presents to us, are those of thunder, and of the water-spout. That thunder and the electric explosion are but different degrees of the same effect, is now well proved, and universally allowed; but it is difficult to shew how the analogy holds between that great phænomenon of nature and our experiments. I would argue thus upon the case: that as the Leyden experiment may be made, not with glass only, but with air interposed between two non-electric surfaces; I would consider the clouds above, and the earth beneath, as these two non-electrics, and the air between them as a plate or medium of separation. So long as the air is humid enough, the intercourse is kept up between the upper and lower region, and the changes which happen in meteorological electricity are brought to pass without commotion. But when the air becomes very dry, (chiefly from heat,) the communication is intercepted, and the two powers are separated. As the clouds assemble and increase, the charge above increases till it

can be sustained no longer; when what I called A in the Leyden experiment, being redundant above, while B is redundant below, (or vice versâ,) an eruption of fire happens to restore the equilibrium. This is rarely done at one explosion, for two reasons: first, because the plate of air, when broken through, recovers itself again, till another explosion makes another breach; and secondly, because the clouds, whence the lightning proceeds, move forwards in the sky, and pass over fresh parts of the earth's surface, which require a like saturation by a new discharge from above.

In the Leyden experiment the discharge is effected two several ways; either by the circuit of the wire or chain, &c. or by a short way, through a fracture of the glass itself, which sometimes happens when the charge is over great. In the sky the effect is brought to pass according to both these methods. The explosion, when violent, will break through the interposed dry air, as it breaks through our glass; but when the rain falls from the clouds to the earth, the same thing is done by the circuit; and perhaps this may account for the difference between the *bolt-lightning* and the *zig-zag*. What I have here said,

said, cannot pretend to be more than a rough sketch from the imperfect idea I have formed in my mind of this great and complex operation of nature, to which we are so frequently witnesses. Times and circumstances produce varieties, and create new difficulties, which demand more accurate solutions than we are or ever shall be able to give. Whatever we may presume, but little is known with certainty to us in the whole subject of *meteorology;* from the comet that blazes in the sky, down to the luminous vapour that dances over the bog. I am nevertheless persuaded, that the compositions, decompositions, and recompositions, which happen in atmospherical air, about which the learned have been so inquisitive of late, will be found to proceed chiefly from combinations, attachments, redundances and deficiences of fire in its electric capacity, if our observation shall be able to follow them minutely enough.

The water-spout seems to be nearly allied to the thunder-cloud, and to admit of a similar solution. Here the two great non-electrics are a dense cloud above, and the water of the sea below: and the preparation is either from a preceding heat or dryness of the air; on which account they are seldom

seen but in climates nearer than ours to the sun. From a thunder-cloud a flash of fire restores the equilibrium: but here, the communication is effected by means of the water of the sea, and the water of the cloud; which, meeting together, form a column consisting of two twisted or spiral shafts; the one from above, the other from below; which whirl together in a furious manner, the one ascending, the other descending, till both regions are reduced nearly to an equal temper; when the column breaks asunder, and sometimes with a flash of light, which plainly indicates what agents were at work on this occasion.

The force of *whirlwinds* is too great to be accounted for by that force of the air which arises merely from rarefaction and condensation. I would rather suppose the water-spout to be a wet whirlwind, and the whirlwind a dry water-spout. They both partake of the same whirling motion; they both pass forward in a line; the one over a tract of land, the other over a tract of sea. Lightning itself seems to partake occasionally of this spiral motion: it having been frequently observed, that trees rent by lightning have borne the marks of having been twisted and

wrung

wrung asunder, as if two contrary powers had acted upon them at once. And this is more agreeable to the workings of nature, than that a gyration should ensue from the motion of a single power. All *eddies* whatsoever are most naturally formed by the meeting of two contrary currents.

I trouble you no more at present with the effects of electricity, natural or artificial: intending to go a step farther in another letter; in which it shall be inquired, (and that not *factiously*, but as candidly and rationally as I can,) how these things agree with some opinions which are commonly admitted; and how far systematical philosophy may be corrected by them. So long as electricity gives us nothing but a *new sight*, we are children: if it gives us new truth, it may turn us into men. Popular error, if it stands in our way, will not suffer us to proceed unless we can remove it: my next letter will shew you what I mean; till when, believe me

Your most obedient, &c.

January 12, 1797.

LETTER IV.

It was observed in my last letter, that a force, such as we discover in electricity, acting by no known laws of projection, gravity, or attraction, must affect some opinions commonly received in natural philosophy: therefore you must prepare to hear me with patience.

There was a time when the two *qualities* of attraction and repulsion, considered as agents of nature, were thought nearly sufficient to govern the world: they were accordingly applied, as to all other things, so to solve the new and wonderful appearances in electricity. A repulsion was supposed between the particles of the electric fluid, and an attraction between them and all other bodies. This was short and easy: but neither of these positions are true; for, if the particles of the electric fluid repelled each other, they would do it most in vacuo, where they have most

liberty to exert themselves. But this does not agree with fact: they diverge most in air, and go in parallel lines through a vacuum. There is another fact of great magnitude, which does not shew that they are attracted by other bodies: for if that were true, how could they flow so freely, as they are observed to do, from the vast body of the earth? If it attracted them, it would retain them; but from the earth they are drawn away more easily than from any other body. The electric fluid is therefore not directed in its motions by these qualities, but by certain laws of impulsion, whatever they may be. When Stephen Grey and Mr. Wheler first made their experiments, it was not to be wondered at, that they never reasoned right; for electricity did not agree with any of the pre-conceived notions of philosophers. And this we may say without any offence to the fame of Newton. Time has brought forth many strange things; but the great work of Newton will always stand the first in its kind, which the capacity of man ever did or ever will produce. Give him ground to stand upon, and he moves the world. With all the properties of the conic sections, and the most profound applications of them, he plays

as freely as the whale plays with the waters of the ocean; sometimes near to the surface, and sometimes at the bottom of the deep, where none but the inhabitants of the same element can follow him. His genius had this great advantage, that gravity, call it what you will, must be admitted as an actual force in nature. It must also be admitted, that the joint effects of compounded forces may be so demonstrated, that the conclusion cannot be denied. But here, in electricity, we have a power doing mighty things, of which power the laws are not yet settled, and perhaps never will or can be, so as to be measured and computed. Of this new power we may be permitted to say something in a new manner, without intending any offence to the fame of Newton. At the time when he surprised the world with his discoveries, the philosophy of Descartes was in possession: who went upon the hypothesis of a subtile matter in the universe acting with a vortical motion; which vortical motion Newton demonstrated to be not agreeable to the laws of nature. *Hypothesis vorticum* is the philosophy he opposes. That he was an adversary to *subtile matter*, does not appear; but the contrary. In Mr. Cotes's preface, indeed, all

all subtile matter is discarded from the creation with an high hand: but that is not Sir Isaac Newton; it is Mr. Cotes, who affirmed too hastily, that *no such thing could be proved to exist, either to the* sight, *or to the* touch. How the fire and force of lightning came to be overlooked, as not existing, or not appertaining to natural philosophy, is a difficulty for which I shall not endeavour to account. Mr. Cotes was admirable at hydrostatics, and many other things; but *pyrostatics,* which ought to stand first in order of nature, are a study for which the learned were not so well prepared then as they are now. The posture of things is very much altered: we have a subtile matter risen up, as evident to the sight in a private chamber, as the lightning itself is in the sky; as evident to the hearing, as the noise of thunder or artillery; and whether it be evident to the touch, let any person judge who has felt the force of it. Here then we have a matter disclosing itself to the *sight,* the *hearing,* and the *touch,* by its appearance, its noise, and its force: that it is *subtile* matter, none of us can deny; for it passes through iron and brass: and if it is resisted in glass, it is resisted by *itself;* for the materials of glass in their

their raw state, discover no such disposition to resist it: and if they resist it in the form of glass, it must be because the glass brings with it from the fire the same sort of matter, seated and fixed in its substance, after a manner we cannot understand; but which gives such an arrangement to its parts as is necessary to its transparency, and occasions those unexpected and obscure fractures to which glass is liable without any visible cause. That it is *matter*, is certain; because it is resisted; which could not happen if it were *nothing*: and its *subtilty* is equally certain; because in other cases it is not resisted, but moves as freely as if it had a power over all other matter.

Contrary to the positive assertion of Mr. Cotes, then, there is a subtile matter existing; and existing every where, in all places and in all bodies; and by what arguments soever it might once be discarded, it is now come again, and will remain with us to the end of the world: and he who thinks it may be left out, and that philosophy may be complete without it, is rather to be pitied than argued with.

It was observed by electricians many years ago, and they were generally persuaded of

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the fact, that the force of an electrical shock is greater when the passage of it is long, than when it is short: and if so, it must rather acquire strength than lose it in passing to a distance; even through hard and solid matter. If this fact be true, it is not within the laws of nature, as hitherto established, Philosophers have taught us, on what terms a force once communicated may continue the same, and how it may change from more to less; but never how it may change from less to more, without the accession of some new force. When a planet is accelerated, as in its approach to its perihelion, this is never supposed to happen, but because it acquires a new force from the power of gravity. But here no such accession is to be discovered: on the contrary, a solid body is interposed, which ought to interrupt the force, and lessen it. The laws of nature, as commonly applied, do not hold in this instance: in the case of artificial or violent forces, they may take effect; but under these the forces of nature are not comprehended. Art goes from more to less; nature from less to more. This is most notorious in the progress and increase of the force of fire, from a single spark to the overthrowing of a city: the consideration of which

which fact so astonished that ingenious man Cadwallader Colden, Esq. of New York, that he denied the *vis inertiæ* to be an universal property of matter.

It was thought, and it has of late been re-asserted, because it is supposed to have received some new evidence, that gravity is common to *all* matter; not as an *effect*, but as a *power impressed* by the Creator; or, as others have worded it, depending only on the *will of the Creator;* but here we have a sort of matter, on which gravity is not impressed, because it is indifferent to every direction; which matter under the power of gravity cannot be. It will appear some time or other, that the cause of gravity must itself be without gravity. It will farther appear, that no solid matter whatsoever, either moveth itself, or is moved by *impressed virtues;* but that all matter which is solid, is moved by other matter which is fluid; and that this is an universal law of nature, to which there is no exception. If gravity were an effect without an impelling cause, it would stand single in the world, and contradict every thing else. For, all motion in matter, so far as it is understood by us, is found to proceed from the motion of other matter, till we

we come to the first cause; and it is neither philosophical nor rational to suppose that the first cause is the immediate cause of gravity, till we are able to shew that no other cause is intermediate. Does it not appear that gravity is a material force, from its being subject to a mechanical law; I mean that law by which it is *added to itself by equal portions in equal times?* That which is immaterial is not subject to be measured by time; therefore gravity is from the force of something which *acts in time*, and is *measured by time;* that is, from some *matter:* and the world can shew us none so adequate to the purpose, as that which is the subject of our present inquiry.

All I have here been saying agrees better with the doctrine of Newton, than with that of his followers. The ingenious Dr. Hugh Hamilton of Dublin, (whose cruel death has of late been so justly lamented,) confessed in his lectures, that "it still remains to be de-"termined, whether these forces of gravity "and cohesion arise immediately from the "will of the Supreme Being; or are the "effects of some secondary or mechanical "cause, which He is pleased to employ in "carrying on the operations of nature. Sir

 "Isaac,

"Isaac, from some phænomena, was in-
"duced to suspect that the immediate cause
"of gravity was mechanical*." Since this opinion of Dr. Hamilton was published, it has been asserted, in the name of the Royal Society, that the doctrine they now hold is that of an *impressed quality common to all matter*†; which is to determine, contrary to Newton himself, and Dr. Hamilton after him, that the cause of gravity is not mechanical, but an unmechanical quality of all matter. I hope I do not misrepresent the worthy President: I do sincerely take this to have been his meaning: and certainly every opinion of the Royal Society deserves respect, because it is theirs. They are a learned body, to whom people who are less knowing ought to look up for true doctrine in philosophy: but I cannot, against the doubts of Newton himself, acquiesce in their doctrine of *impressed qualities;* which, supposing there are such things, enable *inert* matter to *act* upon other matter *without touching!* I am glad this doctrine was never put into the articles of our faith; for I could not have received it: I can as soon believe that

* Lectures, III. p. 86.

† See the Discourse of the President, November 30, 1775, page 4.

that every brass cannon brings its own powder with it from the foundery. But though I say thus much, I am nevertheless persuaded, that many who did believe the doctrine of *impressed qualities*, and argue for it, were persons of good meaning, and great learning: particularly the famous Dr. Bentley, who consulted Newton upon it, and was told that the notion was *an absurdity**. No small nonsense has been engrafted upon Newton; and I may add, no small wickedness: for even atheism has sought a shelter for itself under his name, and would willingly be thought to partake of his wisdom. But his principles, as he delivered them to the world himself, are *mathematical* principles only. Even gravity is used by him as a mathematical force; into the *physical* or metaphysical consideration of which he never professedly entered. Others did it for him, and then put his authority to their own opinions; so that if I am making any opposition, it is not to him, but to them.

Ever since I practised electricity, I have argued thus with myself: that attraction, as observed in electricity, is no *impressed force*; because

* See his Letter to Dr. Bentley, in the 4th vol. of Bishop Horsley's edition of Newton's Works.

because I try it on the air pump, and I find, that when I take away the air, that impression is gone, though it is then most at liberty to act and shew itself. I argue again, that attraction cannot belong to the solid parts of matter, because I take the light shavings of amber, the most attractive of all electrics; and I find that the same particles which were *attractive* in the mass, are now *attracted* in the parts, like those of any other body. I therefore conclude, that as the same substance cannot be both active and passive in its constitution, the cause of its attraction must be something not inherent in its parts, but adventitious or external to its own matter. Having got thus far, I make a transition from the force of electricity to other forces; and I still conclude that as this attraction is not in the solid parts, but in something adventitious, the same will be the case with other attractions; and all upon this principle, that nature is uniform in its operations and laws: I therefore go on to conclude the same of cohesion, chrystallization, the action of menstruums, chemical elections, &c. &c. How subtile the cases may be I care not, nor how disguised by words: the quality called attraction always was a phantom from the

the beginning, and I believe no more of it than I do of the stories about ghosts.

I say farther, that if I can prove attraction to be from an external cause in any single instance, I may *think* the same of it in every other instance, whether I can prove it or not: and I shall think rationally, because I think consistently. On the other hand, if any person advance any one sort of attraction, with an exterior cause, he must extend his principles to every other case in nature, to make nature consistent. But in this he will never succeed; and he may thence infer, that his principle was not right at the beginning. If any learned gentleman can suggest to me a better train of reasoning than this into which I have fallen, I will hear him with patience, and go over to his side of the question. I have no attachment to any thing considered as mine: all the philosophic fame in the world is no object with me; let Dr. Priestley have it all, who has been courting it for so many years. But truth is a great object; and the more so, because truth in one subject breeds truth in another, and *vice versâ*.

The argument I am now pursuing may be extended to Kepler's Law, which is known

to, obtain in the heavens, and confirms all I have said. For, as it was observed above, a mechanical law must be the law of a mechanical force: if it measures matter, it must have matter to measure; for spirit is not the subject of geometry. Any mechanical law will certainly suit better with the force of a *fluid*, which is mechanical, than with the force of a *quality* which is unmechanical. What Kepler himself might have produced out of his own law, if instead of his old speculations he had been guided by the new discoveries of modern times, it is above me to conjecture. Whoever reads his Epitome of Astronomy, will find that his head was filled with the mystical idea of attraction from Gilbert's Magnetic Philosophy, and his mind much given to fanciful speculations on geometrical solids. But so it came to pass, that out of all his fancies that wonderful discovery emerged, which is the foundation of modern astronomy.

I observed to you at the beginning of my first letter, that the science of electricity rose up in the world at a remarkable time; and so you will think, if you consider it. Newton had found, that the heavens contain

such matter as cannot be discovered to make any resistance to the celestial motions: which is reasonable and true; for the cause of motion, whatever it may be, will never be found to resist the motion which it causes. But his followers went a step farther, and emptied the heavens of all their matter. Things were in this state when the new powers of electricity broke in upon us. You may think they came at the moment when they were wanted; and so I think: but if we were to judge from the little use which has been made of them, they came at a time when they were not wanted; when those who were most learned in philosophy did not know what to do with them; as supposing that the whole business might be done without them, and that they could only stand in the way and be troublesome: for new governors bring new laws; and new discoveries, so different from the old, will bring new thoughts. I wish Newton had seen them: he would have pursued them, and brought something great out of them. But without him, who dares to begin? and if he does begin, who will thank him for his labours? for labours of which the world feels no want. Thus it hath came to pass, that electricity has given us no new principles;

in that respect we seem to have been at a stand for many years: if we have been progressive, it has been chiefly in the application of it to the cure of bodily disorders, where it has been of great use. In this capacity I shall therefore speak of it in my next letter.

I am, Sir, &c.

Jan. 15, 1797.

LETTER

LETTER V.

Among the remedies of diseases, there is a class which may be called philosophical: by which we mean such remedies as are independent of the apothecaries drugs and the surgeons instruments, and consist chiefly in the proper use of the elements. These, being nearly related to the powers of life, may reasonably be expected to do much good or much harm. The qualities most obvious in the elements are those of heat, cold, moisture, dryness; nearly related to which are diet, exercise and clothing. Heat and cold are powerfully applied in the form of the hot and cold bath; to which the vapour-bath has of late years been added with great effect: but one of these must not be used when another is more proper. The natives of America, when the country was first discovered, had a method of curing fevers by sweating, first in a hot room, and then plunging into cold

water: the intention of which was, first to let the enemy out, and then to shut the door upon him. But when these poor people applied their old method to the small-pox, they killed instead of curing themselves. Dryness of the air is generally wholesome; whence the inhabitants of mountainous countries are more hardy than those of vallies and marshes. Yet moisture is in many cases serviceable; but *cold* moisture draws off the animal heat, and diminishes the vital powers. Near to the sea, if there is a clean shore, the air is more pure than within the land: and the mere air of the sea, from some quality not perfectly understood, has a specific power in removing severe coughs which will not yield to medicine; as I found by experience twice in the course of my life. In common meats and drinks there is nothing of medicine: but the proper use of them is of the first importance; for which cause the dietetic part of physic is much studied by physicians and well understood. Often might sick persons be relieved by the observance of some plain regimen, without the use of a single medicine: and the remedy has two advantages; it is cheap, and it is lasting. But how and when shall we give wisdom to the idle and the intemperate?

In

In the subject of our clothing we have now some knowledge which is entirely new: for the garments we wear are distinguishable into electric and non-electric; the effects of which upon the body are essentially different; for the former retain its natural heat, and the latter draw it off. To land animals in general, the Creator, in his wisdom and bounty, hath given a sort of covering, which keeps up and keeps in the heat of the body; and common sense teaches us to borrow it from the animals to which it is given. Hair, wool, feathers, silk, are among the substances which we call electric. How proud and vain are men and women when they are clothed with silk! but the first use of silk is to preserve warmth to a poor worm in its intermediate state. Linen on the contrary is cold, because it is taken from a vegetable, whose nature it is to conduct and carry off animal heat. Electricity has taught us to reason well about these things, and consequently to act with more safety and propriety. Many chronical disorders have been cured, or very much relieved, by the wearing of flannel next the skin. The fact is commonly known; but the reason is now better understood. We know not of a single animal, but man, that

wears a non-electric next to the body. The first clothing man made for himself was taken from a vegetable: the first clothing the Creator made for him was of skins*. It is very observable, that hair and wool, and feathers and silk, do not easily take fire; they have it already in their constitution: but linen of all kinds receives it readily, having less of its own. It therefore makes good tinder, which can never be made of silk, hair, or feathers: touchwood, which is natural tinder, is also from a non-electric. In short, the new principles of electricity have taught us to account for these differences, and the subject of human clothing is become at once curious and useful. The sensations also with which various animals are affected on changes of the weather, are now better explained than formerly, since we have known more of the changes of electric fire in the atmosphere. For the barometer alone, as indicating only the different weight and superficial pressure of the air, cannot account so well for that inactivity in the muscles, and those pains in the joints, which different states of the atmosphere produce in us: but minute changes in that fluid which acts upon the internal parts, or whole dimen-

* See Gen. iii. 7, 21.

dimension of bodies, and has power to penetrate the frame and shake the bones, may be adequate to all that happens in this way.

On all the foregoing considerations, we have reason to wish that electricity may never cease to be administered as a philosophical remedy, under some form or other. Physicians have said much on what they call the *non-naturals;* by which they mean such things as are exterior, and not of a medicinal kind. They have reckoned them six in number: this new power may now be added to them as a seventh.

There are five different modes of applying it. The first is a communication of it to the whole frame at once; which is what we understand when we say a person is *electrified.* The second is under the form of a *spark;* which may be stronger or weaker according to the power of the apparatus, or the intention of the operator. The third is the friction or flesh-brush; of which method there is a good figure prefixed as a frontispiece to Mr. Adams's Essay on Electricity, designed by an eminent artist. The fourth is that of a topical brush from a pointed wire; or a point of wood, which renders the brush more soft and

and gentle. The last is the electric shock from the circuit of the Leyden bottle. The spark is the form I commonly prefer. If strong, it may be received at any point of the body, and discharged at any other point; in which case it certainly passes in a line from the one to the other.

The electric friction, or flesh-brush, is an excellent form for rheumatic pains and paralytic affections; and it occasions a thrilling sensation, by which the spirits are remarkably raised, as by a cordial. But in cases where the *shock* is proper, it is the sheet-anchor. It completely restored the use of the limbs the first time. I had an opportunity of trying it on an hemiplegia: but the party was young, and of a strong frame, and the disorder arose from an accidental cold. Agues, after resisting the bark, have frequently been cured by it. Medicines are remarkably forwarded in their operation by the use of electricity. A blister may be made to run which did not run before; and a cathartic, if slow, may be made quick; sometimes very quick; which it may be useful to know in case of a stoppage. It is the only remedy for gutta serena, and very often succeeds. The fluid is generally used for gutta serena. I would observe,

upon

upon the whole, that, if a complaint is recent, and the patient young, great things may be done: if the complaint is recent, and the patient not young, something may be done. But if the complaint is of long standing, and the patient not young, little can be done: yet even then there are cases when an application of this remedy may palliate, and therefore be worth trying. It is now so far adopted by medical gentlemen, that an electric machine is reckoned a necessary part of the apparatus in hospitals; and many surgeons are furnished with one in the country; the ordinary use of which is in paralytic cases. It has been hinted to me, however, that the cobwebs are too seldom brushed off from hospital machines, and that the general answer of the faculty has been, they are too old to go to school again. It may certainly be extended to many other disorders with advantage: and the practice is in the hands of ingenious men, who make proper observations and keep journals of their proceedings in this part of philosophy. Many extraordinary cures have been performed by electricity, and several cases have been read and published by the Royal Society; but how it happens that physicians know so little of this wonderful

power,

power, I am at a loss to account. Every year presents some new empiricism to them, which rages for its time and is buried in oblivion. Magnetism has had its advocates, hemlock, inspiration of medicated airs, and now the vitric acid, and the tractors; but the cures by electricity stand uncontested, and the cases published (as a sequel to George Adams's Treatise on Medical Electricity) are so strong that no doubt can arise.

But unless a man has a mechanical turn, and is perfectly master of the instrument, he will so quickly put it out of order, that his experiments will stop. If a man would perform on the violin, he must know how to keep it in tune; and although many symptoms of a disorder may be relieved by the accidental application of electricity, yet in the hands of a person skilled in the anatomy of the body, and the cause and seat of diseases, much more may be expected.

The modes of applying it may be so varied that, to an observer, it would appear more like magic than science; yet all the modes are to be reduced under three heads—the stream which passes from a point, the spark which flies from a ball, and the shock of the Leyden phial. It may be extracted from the body in the

the same manner as it is directed towards it, by insulating the patient; or two sensations may be produced at the same moment, for the stream may be directed in at the eye from a glass-handled director with a point, and sparks may be drawn from any other part by applying a metallic ball.

I would not infer that, in so liberal a profession as medicine, the desire is not to cure; yet, when I hear the far greater part of a faculty speak against so powerful an application, without having any knowledge at all of it; and when the most skilful must acknowledge they have seen good arise from it, where it was least expected; I am led to suspect there is a cause to suppress it. It was many years before James's Powder was prescribed by the College, and even now a spurious substitute is introduced in lieu of it at the Apothecaries Hall, under the title of *Pulvis Antimonialis*. Electricity, however, is more likely to become a branch of surgery, because it is a manual operation; and surgery is making hasty strides towards improvement.

I say no more on the application of electricity to the *Microcosm*; that is, to the system

tem of the human frame. If we can apply it with any success to the *Macrocosm*, or frame of the world, we shall make a new step in philosophy: and this is what I shall attempt in my next letter.

Dear Sir, ever yours, &c.

Jan. 17, 1797.

LETTER

LETTER VI.

Sir,

When we bring electricity into a chamber, we know what we are about to do with it: but when we bring it into the *world*, who can say what it does, or what it cannot do? Before we can proceed upon this great question, it is to be remembered, that the principles of every science lie within that science itself; as the elements of every language are to be found in its own alphabet. One language gives help toward the knowledge of another: so are all the sciences related in like manner: but we are not to apply to one science for the principles of another. When philosophers amuse themselves with the balancing of weights, or the striking of balls, they are very ingenious men: but all this is the work of art; from which little can be gathered concerning the ways of nature. If nature is to

to be explained, we must apply to nature itself; the principles of which have of late been so much farther opened to us by the discoveries in electricity that I shall take them chiefly from thence, and apply them in such a manner as I think you will easily comprehend.

The farther we inquire into the ways of nature, the more clearly we shall see that one grand principle is every where at work; which is that of contrary motion in two contrary powers. You must have seen something of this already from the foregoing letters; for it is no where more conspicuous than in the experiments of electricity; but the same principle meets us every where. Who would attempt to account for the eddies we observe in magnetism, without supposing two such powers? We can neither see them, nor can we feel them, for we are not made of iron. If we speak accurately, we must not say that these powers are in iron or the loadstone; but that the powers themselves are in nature, and the *effects* of them in iron and the loadstone. It is easy to prove this: for, let a simple bar of iron be any where placed in a vertical position; two powers are immediately found to act upon it, which cannot belong
to

to itself. The top of the bar draws the north end of the needle, and the bottom draws the south end. To prove that these powers are not in the iron, but adventitious to it, invert the bar; and the same end which in its former position drew the north end of the needle, will now draw the south end. What happens therefore is not from the iron itself, which is a passive body, but from some occult circulation in nature acting upon it; which is constant and regular in nature, but variable in the iron. The like effects will follow, if the two ends of the bar, which before were vertical, are alternately placed north and south in the direction of the magnetic meridian. These wonderful things are brought to pass by two powers, which, though contrary in *effect*, are one in *kind*.

In the body of man, it is now universally known, that life is kept up by a contrary motion: and the ingenious Dr. Woodward took great pains to shew, that the seat of life is where that motion is; I mean in the *blood*: in which doctrine he is followed by the late Mr. John Hunter. And if from the body of man we make a transition to the body of the earth, we observe a like reciprocation in its winds and waters, in the breezes of the land and

the sea, in tides and currents, in the cold of the poles and the heat of the equator. All things are going out, and all things are coming in; and the returns being equal, though contrary, nothing is stopped, nothing is lost or wasted. Whatever others may find, it is in this certain and wonderful analogy that I have found the philosophy which has always been to me the most satisfactory *. Let us only continue it to the heavens, where it must prevail if Nature is consistent, and we shall have all we want; with the application of which, we may proceed as far as we can wish, or at least as far as we ought to wish, under the present imperfect state of human knowledge.

What strange effects two contrary powers will produce, we have already seen, from the example of the little revolving electrical globe. We see *that* situated between one of them which brings it forward, and another which drives it off; and their joint action upon it carries it round. With whichsoever of

* This principle of contrary motion, as produced by the interchanges of heat and cold, has lately been opened and applied with great truth and ingenuity by Count Romford, in his 7th Essay. Heat and cold are two of Nature's hands: the contrary powers of electricity are two more; and there be many others constantly at work.

of these you may think it proper to begin, the solution comes to the same: for, while the repelling cause acts on one side to turn away the point electrified, the attracting cause brings a fresh point forward; and thus the globe exhibits a rotation round its own axis, and a revolution in an orbit. The fact is undeniable, and the causes are undisputed.

If, for the sake of illustration, it be lawful to whip a painted top, and gather from thence a good reason why the sun looks white; we may also be allowed to argue from this little sphere and its motion, to the great ball of the earth. In our present state of existence, we are under the necessity of learning great things in this childish manner from little ones: and we ought not to be ashamed of it, for we cannot otherwise conceive them. I have therefore often amused myself, and I do so to this day, with considering my electric apparatus as a system similar to that of the heavens; where the sun is the grand electric globe, exciting all things to an active state; while the earth and its atmosphere are conductors, distributing and applying to all bodies contained within them the force and life they derive from the centre. Kepler

formerly considered the sun as the *great magnet* of the world, with an attractive side and a repelling side; and that, by the influence of *both*, he carried things forward: but we are now upon better ground than he was. We have realities before us, and have no need to call in occult qualities to our aid. For if the sun be the beginning and end of a circulating matter in the heavens, then will every orb, however it may be placed, be situated between two powers; in which situation it can no more continue at rest, than the little sphere between the two powers of electricity. One of its hemispheres will be toward the sun, the other will be away from it: consequently the one will be in light, the other in darkness; the one will be heated, the other will be cold: they will therefore be in two different conditions. This Nature never permits, without an effort to restore an equilibrium, which equilibrium, if destroyed as fast as it is restored, can never be restored at all; and the constant effort of Nature to effect it, produces a perpetual motion. If the two powers are equally balanced, the orb between them will always move at the same distance, and the orbit will be a circle: if

they vary, or prevail over each other alternately, the orbit will be elliptical, and the sun will be in one of the foci.

You will say, perhaps, that this solution may be admitted in the case of a primary planet; but what are we to do with the secondaries? For we refer the primary orbs to a source of light; but the secondaries to an opaque body; and must not these cases essentially differ? So it was thought, and very rationally, at the beginning of this century: but electricity hath now taught us, that the effects are the same whether the central body be opaque or lucid. The little sphere will revolve round an opaque body, placed at any distance from the electric fountain. In the motion of a secondary orb, there is now no more difficulty than in that of a primary: and there is the same reason why the law of Kepler should take place on the secondary with respect to the primary, as on the primary with respect to the sun. We cannot indeed assign any reason, why the progress of a planet should be from West to East, rather than from East to West: but we may presume to say, why the motion, when it has once commenced in that direction, will persevere in the same; from the causes

causes which are known to act upon it. What these causes are, let us now consider.

The earth, at its western, or evening edge, having been exposed throughout the whole day to the action of the sun; and the eastern edge but now coming out of the night into it; the eastern and western edge cannot both be in the same condition. This produces an inequality, which is all we want; for a force will thence be generated in the heavens on the western side, to propel the earth in its orbit. And with this direction in the earth the most ancient account of the creation seems to agree; where, in order of time, it sets the evening before the morning: which is proper, if the first impulse commenced at the western side of the earth. The greatest agitation of the day being on the west side of the meridian, there the power will chiefly act; and the earth will be moved toward that side where the action is weakest. But if this is to be effected by impulse, you may possibly observe, that it must require an immense impulsive force to carry forward, with so much velocity, a body of such magnitude as a planet. But in this we should argue like children: for, though a planet be to our conception an immense unwieldy body, it is well

4 known,

known, to philosophical men, that a force which in the beginning is less than any assignable quantity, may amount to any thing required, if it be added to itself by continual increments, like the power of gravity.

This, Sir, I must confess, is nothing more than a hasty sketch of one of the first and greatest operations in the universe: but of the principles in gross, on which it goes, I have no doubt. The forces employed in it are none of them petitionary; but real, and necessary, and adequate. I say they are necessary, because no motion can be continued in a *natural* way, if we suppose the first impulse to arise from any violent, artificial, or transient force. Because such a force, as I have already observed to you, always changes from more to less; whereas the forces of Nature are from less to more. You have a familiar proof of this doctrine every time a body is thrown upwards. A violent force carries it up, which is greatest at first; a natural force brings it down, which is greatest at last. And I will venture to add, that if the earth could be stopt in its course, its motion, when the obstacle was removed, would be renewed on its own principles: because a body,

body, situated under such circumstances as the earth is, cannot remain at rest.

Plain as these principles are, I will call him one of the most ingenious and knowing amongst mankind, who shall be able to collect the necessary data, so as to bring this affair to a calculation. The parallelism of the earth's axis, and the obliquity of the ecliptic, forming so nearly the same angle at all times with the equator, must require such a balancing of powers as we can never hope to comprehend: nevertheless I can easily believe, that the powers, of which I have been treating, are adjusted with the utmost exactness to the intended effects. And, to my understanding, it will always be more easy to conceive how an effect of any kind may be brought to pass *with* natural means, than *without* them. The very eccentric motion of a comet is more agreeable to the effect of an electric power, than of any other power we are acquainted with. Who hath ever yet appeared to know what becomes of it in the superior part of its orbit? I would not depreciate the labours of learned men, without some good reason. Dr. Halley bestowed much time and great labour in working upon the

the elements of cometary orbits, and thought he had reduced them to a system for the benefit of all posterity: but I believe it has never been found by experience, that they have been of any real use in astronomy. I have more satisfaction, and think it more to the purpose of physical astronomy, when I see a light body so nearly imitating (as it often happens) the motion of a comet about an electric conductor; first approaching, then partly surrounding, then flying off from it, without first falling into it. A phænomenon so similar directs us to a cause better accommodated to the motion of a comet in the heavens, than any hitherto assigned by the learned.

So long as the natural world goes on in its regular course, (the moral world, God knows, is very much out of order,) we ought to be thankful. But I sometimes figure to myself what may happen, if the solar system could suffer disorders similar to those which befal the system of man's body; on a supposition that the sun is (as the ancients held it to be) the heart of heavens. When the capillary vessels at the extremities are stopt, the force of the heart is increased, the blood is accelerated in the arteries, and the effect is a

 fever.

fever. Thus, if the circulation of the heavens could be obstructed at the orbit of Saturn, the force of the sun would be increased, and the earth would be whirled about with a swifter motion, which would tend to its dissolution. But while the powers of the heavens are justly balanced, according to the intention of the all-wise and beneficent Creator; the world is in health, and its revolutions are quiet and regular: we hear no confusion, we feel no disorder; but all goes on in silence for our good. Mankind are always desirous of penetrating farther into the wonders of the solar system. Telescopes, ever since the days of Galilæo, have been constantly at work to explore new mysteries, which amaze and perplex man's understanding: and in consequence of this, we amuse ourselves with conjectures, with little prospect of finding out the ways of God to perfection. Different ages have gone upon different principles. Magnetism had its day: vortices were in great repute: gravitation (as a power *impressed* on matter) is now reckoned all-sufficient: but I think we stand at this time on fairer and firmer ground; electricity having raised us to a point of view, where a new field is opened before us,

of

of more promising speculation than was ever yet known to the world. But bright and open as the prospect may appear, we must never hope to keep clear of great difficulties and obscurities. In what I have now written to you, I must be content to partake of the common fate: on which consideration I must beg of you to accept with candour what I havé offered to you in great friendship; and to add to, or correct my observations, as you shall hereafter find occasion. Slight and imperfect as my sketch may have been, I am persuaded that I have set before your eyes an idea of *the Solar System at work,* such as your mind will contemplate with new and increasing pleasure; and on which it will perhaps be hereafter employed, to your own amusement, and the improvement of other contemplative men. With this expectation I bid farewel for the present to you, as well as to this great and curious subject; and am,

SIR,

With great affection and esteem,

Your most obedient,

Jan. 27, 1797.

THE END OF THE TENTH VOLUME.

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